AD NUMBER
AD072686
CLASSIFICATION CHANGES
TO: **UNCLASSIFIED**
FROM: **CONFIDENTIAL**
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Controlling DoD Organization: Nval Ornnance Lab., White Oak, MD.**
AUTHORITY
31 Dec 1963, DoDD 5200.10 ; NSWC ltr 4 Dec 1974

NAVORD REPORT 2262

EFFECT OF LOADING VARIABLES ON THE BURNING CHARACTERISTICS OF DELAY POWDERS

19 December 1951

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

EFFECT OF LOADING VARIABLES ON THE BURNING CHARACTERISTICS OF DELAY POWDERS

Prepared by

E. E. Elzufon

ABSTRACT: A study has been made of the effect of loading variables and obturation on the burning characteristics of delay powders consisting of manganese, barium chromate and lead chromate. The effects of increment size, quantity of igniter used, inside diameter of the delay body, type of loading ram and loading pressure were investigated. Recommended limits for the loading variables are presented. The maximum increment size and also the permissible increment size variation decrease with a decrease in body diameter. The increment size in ⅜203 I.D. delay bodies was varied between 200 and 700 mg without an appreciable effect on the burning rate. The amount of igniter charge can affect the burning characteristics of the delays. Fifty, thirty, twenty, and twenty mgs of igniter are recommended for delays having internal diameters of ⅜203, ⅜156, ⅜125, and ⅜109 respectively. The smaller the diameter of the delay body, the more difficult it is to obtain sustained burning of the slow burning compositions. Although the slowest mixture (.08 inch/sec) burned satisfactorily at -65°F in ⅜203 diameter bodies, the mixture failed to burn in ⅜156 diameter bodies. Loading pressures between 21,200 psi and 38,800 psi were found to have a negligible effect on the burning rate of the delay powder. Obturated delays were found to have a burning rate approximately 30% higher than vented delays. It is concluded that the burning characteristics of the compositions studied are primarily a function of the formulation. The loading variables will not appreciably affect the burning time of the delay providing they are held within the recommended limits.

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

NAVORD Report 2262 19 December 1951

This Report outlines the results of a study of one phase of the project, Development of Gasless Fuze Powder (NOL-Re2e-104-2). The investigation was made to determine the effect of varying the loading parameters on the burning characteristics of manganese, lead chromate and barium chromate delay powders; and to recommend limits within which they could be varied without adversely affecting the burning characteristics. The results of this investigation are intended for the use of the Naval Ordnance Laboratory and should be of interest to other activities engaged in developing pyrotechnic delays.

References

(a) NAVORD Report 1773, The Development of Mixing Procedures for Gasless Fuze Powders, 22 Jan 1951
(b) NAVORD Report 1814, A Method of Protecting Metal Powders from Deterioration, 18 Apr 1951

W. G. SCHINDLER
Rear Admiral, USN
Commander

S. W. BOOTH
By direction

CONTENTS

ILLUSTRATIONS

Plates 1-25

EFFECT OF LOADING VARIABLES ON THE BURNING CHARACTERISTICS OF DELAY POWDERS

INTRODUCTION

1. A pyrotechnic delay powder composed of manganese, lead chromate, and barium chromate, is at present being considered for use in a variety of ordnance devices. In the design of the required delay elements, knowledge of the effect of various loading variables on the behavior of this powder is required. A study therefore has been made of the effect of the following variables on delay behavior:

a. increment size in loading

b. size of igniter charge

c. body diameter

d. type of ram

e. loading pressure

f. venting and obturation

Procedure

2. In making these studies, a variety of mixtures was used. All were prepared in three pound batches according to the procedure outlined in reference (a), using Mn pretreated according to reference (b), methods f and g. The burning times and the compositions of the mixtures investigated are listed in Table I.

3. These investigations included both vented and obturated delays. The delay bodies, procedure for loading the compositions in the bodies and the delay assemblies are shown in Plates 1 through 5. The delay columns in all cases were loaded at 30,000 psi except when delays were prepared to investigate the effect of loading pressures. In loading bodies using the cone ram, the igniter and the adjoining increments at both ends of the delay powder were pressed together. In flat ram loadings all increments including the igniter were pressed separately.

4. The firing jig for the delays is shown in Plates 6 and 7,. The delays were timed using the method outlined in reference (b). Vented bodies were initiated with Dupont S-67 electric squibs. A base charge of about 15 mg of black powder was used in the vented delays. The completely obturated delays were initiated with a low energy electric initiator that contains 5 mg of lead styphnate. The base charge in this case was a smokeless powder pellet or a 70 mg black powder pellet.

5. Cold tests were run in a temperature controlled room at temperatures varying from -70° to -60°F. The firing jig heated up to about -55°F maximum during the firing runs. High temperature tests were run in a small box with temperatures varying from +155° to 170°F. The temperatures of the firing jig were not taken during these runs.

Increment Size Studies

6. In an effort to determine the effect the increment size of the delay powder has on the burning time of these delays, the following tests were carried out. D-7 mixture was loaded in .203 diameter bodies, in increment sizes as indicated in Table II. These were fired at room temperature and the burning times recorded in Table II and plotted in Plate 8. The results of this test indicate that increment size affects both the height of the delay column and the resulting burning time for a given weight of delay powder. However, Plate 8 indicates that within these limits the burning times in seconds per unit length of delay column is constant regardless of the increment size used.

7. A more thorough study was then made of the effect of increment size on delay burning times and column heights in .203 bodies. The data taken are shown in Table III and plotted in Plates 9, 10 and 11. Burning time and column height data indicate that if increment size variations are kept within reasonable limits the effect on the burning characteristics of the delay will be negligible. For .203 bodies it is recommended that delay powder increment sizes be kept between 200 and 700 mg. Burning times of delays loaded as recommended may be considered directly proportional to column height and both in turn proportional to the weight of delay powder used provided that the diameter of the column and the loading pressure are held constant.

8. Mixtures F2, M2, S2 and X2 were loaded in .156 bodies with increment sizes varying from 100 to 300 mg. These delays were fired and timed and the results recorded in Tables IV, V, VI and VII. These results were plotted on Plate 12. Results indicate that for these mixtures varying the increment sizes from 100 to 300 does not affect the burning times of the delay. It is recommended that for .156 bodies increment sizes be kept in this range.

9. Mixtures F2 and M2 were loaded in .125 bodies in 75, 150, and 250 mg increments. These delays were fired and times recorded in Tables VIII and IX and plotted in Plate 13. In mixture M2 the 250 mg increments gave shorter burning times than would be expected. This seems to result from delay powder getting between the ram and the walls of the delay body, thereby causing excess wall friction and reducing the effective loading pressure. It is therefore recommended that in .125 bodies increment sizes larger than 150 mg be avoided.

10. In a similar manner the data listed in Tables X and XI, and plotted in Plate 14, show that for a .109 body, increment size of the order of 200 mg produced faster burning rates than expected. It is recommended that in .109 bodies increment sizes not exceed 125 mg.

11. The foregoing indicates that the optimum increment size for production loading of delay columns should be selected not only with an eye towards getting the smallest number of increments but also towards getting an increment size that is small enough to eliminate the probability of loading irregularities due to excessive wall friction.

Minimum Igniter Studies

12. In order to determine the minimum amount of igniter powder, which would reliably ignite these delay powders at all temperatures, a slow burning mixture with a specific burning time of over 14.0 seconds per inch was used. These delays were loaded in ".203 bodies using the rams shown in Plate 15 and the methods illustrated in Plate 16.

13. The results of this study (see Table XII) indicate that regardless of the loading procedure used, 20 mg of F33B igniter will give ignition at 77°F. However, at -65°F 20 mg will give ignition only with flat ram loading. However, 50 mg did provide ignition in all delays at all temperatures.

14. It is recommended that in loading delays in ".203 bodies a minimum of 50 mg of igniter be used. In cold box tests of smaller diameter delays (see Tables III through X) smaller charges of igniter were used and found to be satisfactory. The following charges are therefore recommended as minimum for all diameters:

".203	50 mg
".156	30 mg
".125	20 mg
".109	20 mg

Body Diameter Studies

15. At times, because of space limitations, it becomes desirable to decrease the size of the delay body to a minimum. In the design of a delay column it is important to know what burning area is required to provide sufficient heat for the self-burning propagation of the delay column. For this reason, studies were made to attempt to relate the burning characteristics of the delay column with burning rate of the composition, diameter of the burning area and the temperature. Delay bodies having internal diameters of .203, .156, .125 and .109 inches were used in these studies. The delay bodies were loaded with compositions that had burning rates in the order of 0.36 to 0.08 inches per second at room temperatures. Burning rates were calculated graphically from Plates 12, 13, 14 and 19. The results of these tests are shown in Table XIV. The height of delay column, weight of delay powder used and delay column diameter have the relationships shown in Plates 21, 22, 23 for all the mixtures used.

16. The delays were tested at room temperature (77°F and -65°F). Mixture F2 which has a burning rate of approximately 0.35 inches per second burns satisfactorily in all diameters at all temperatures. Mixture M2 with a burning rate of approximately 0.11 inches per second burns satisfactorily in all bodies at 77°F but produced duds when burned in ".125 and ".109 bodies at -65°F.

Mixture S2 with a burning rate of approximately 0.09 inches per second burns satisfactorily at all temperatures in ".203 and ".156 bodies but failed to burn in ".125 or ".109 bodies. Mixture X2, the slowest mixture used in this study at a burning rate of 0.08 inches per second burned at all temperatures in ".203 bodies, but only at room temperature, in ".156 bodies.

17. The above results indicate that there exists a relationship between burning rate, column diameter and ability to sustain burning at various temperatures. The quantitative determination of this relationship was beyond the scope of this task.

Effect of Different Rams

18. In the ignition of some types of pyrotechnic mixtures a cone or stepped ram is used to increase the ignition area. However, loading with a cone ram is more difficult than with a flat ram due to the tendency of the composition to adhere to the surface of the cone. In order to determine whether a cone ram is necessary for the reliable ignition of this type of delay column, a study was made using two different rams as illustrated in Plate 15 and loaded as previously mentioned in Plate 16. Table XII indicates that there is no significant difference in ignition due to the different rams used. However, a cone ram shortens the effective column length of the delay train thereby giving reduced total burning times. Data given in Table XIII and plotted in Plates 17, 18, 19, and 20 illustrate this point.

Effect of Varying Loading Pressures

19. In order to determine the effect of the loading pressure on the burning characteristics of the delay column, the following test was conducted: Delay columns ".203 in diameter were loaded with 50 mg of F33B at the primer end, 30 mg of F33B at the base end, and three increments of 350 mg of M2. Five bodies of each were loaded at varying pressures as shown in Table XV. These data indicate that loading pressures between 21,200 psi and 38,800 psi have a negligible effect on the burning rates of these powders. The main loading pressure of 30,000 psi was varied $\pm$ 29.4% resulting in burning time changes of $\pm$ 3.5%, burning rate changes of $\pm$ .08%, and variations of packed column heights of $\pm$ 2.6%. Thus for loading pressures in this range (30,000 psi) the effect of changing the loading pressures would be negligible if these variances are kept within $\pm$ 5%.

Effect of Obturation on Burning Rate

20. In the design of delay elements the question of relative behavior of vented and obturated delays arises. In order to get information regarding the effect of obturation on the burning rate of the delay the tests described below were conducted. Bodies shown in Plate 4 were loaded and assembled as indicated in Plate 5 for these tests. All loading was done with flat rams. The over-all length of these bodies was 1".790 $\pm$ .005, providing a space of approximately 0".910 for the delay column. Two series of bodies were loaded for this test as follows: (1) Series A was loaded with 50 mg of F33B at the primer end. Varying amounts of delay powder mixture M1 were used and any cavity remaining at the base end was filled with F33B powder. (2) Series B was loaded with varying amounts of mixture M1 and 30 mg of F33B at the base end and any cavity remaining at the primer end was filled with F33B.

21. Burning times are given in Table XVI and the results are plotted in Plate 24. In Plate 24 burning times are plotted against the column length of the delay train. The slope of line A indicates that without an excess of igniter at the primer end a burning time of 6.50 seconds per inch is obtained at room temperature. This compares with a burning time in #203 vented bodies for M1 of about 9.20 seconds per inch at room temperature. Therefore, the obturated delays tested burned approximately at a 30% higher rate than the vented delays. In obturated delays the effect of excess igniter at the primer end is greater than in vented delays. Line B in Plate 24 illustrates that with excess igniter the burning time is not necessarily a linear function of column length. Therefore obturated burning rates greater than 30% above vented burning rates can be expected if excess igniter is used.

Recommendations

22. It is recommended that loading variables be kept within the limits specified in Table XVII. It is further recommended that flat rams be used in all loadings of these delay powders. It is further recommended that vented delays be used whenever possible in the design of fuze trains.

CONCLUSION

23. The burning characteristics of loaded Mn-$PbCrO_4$-$BaCrO_4$ delay powders are a function primarily of the formulation. It is not feasible to appreciably change the burning rates of delays by varying the loading parameters. Plate 25 indicates that for different mixtures there is a linear relationship between specific burning time in inches per second and the burning time for delays loaded in the same manner.

TABLE I

Chemical Compositions and Burning Times (at 77°F)
of the Mixtures Used in These Studies

Mixture Designation	Composition (weight %) Mn	$PbCrO_4$	$BaCrO_4$	Specific Burning time sec. per inch
F-2	43.2	52.3	4.5	3.0
F-1	43.8	53.2	3.0	3.2
M-2	33.4	37.6	29.0	8.6
M-1	35.0	40.0	25.0	9.2
D-7	34.3	37.2	28.5	9.8
S-2	31.4	34.6	34.0	11.0
X-2	29.8	32.2	38.0	12.4
X-1	31.4	34.6	34.0	12.7

TABLE II

Burning Times and Column Heights of Delays Loaded With D-7 in Varying Increment Sizes in .203" Bodies

(Igniter: 50 mg F33B Primer End, 30 mg F33B Base End, Flat Ram)

Delay Charge Total Weight	Increments	Symbol on Plate 8	Column Height	Burning Time
1400 mg	2 of 700		.701	5.65
"	"		.676	5.47
"	4 of 350		.650	5.39
"	"		.047	5.24
"	"		.646	5.37
"	7 of 200		.622	4.96
"	"		.638	5.13
"	"		.633	4.91
700 mg	1 of 700		.360	2.77
"	"		.361	2.72
"	2 of 350		.342	2.66
"	"		.350	2.77
"	4 of 175		.341	2.71
"	"		.343	2.68
"	"		.340	2.77
"	3 of 200		.340	2.67
"	1 of 100		.330	2.59
"	"		.340	2.56

TABLE III

D-7 Loaded in .203" Bodies

(Igniter: F33B-100 mg Primer End, 70 mg Base End, Cone Ram)

Increment Size	Mg	350	350	350	350	250	250	450	450
Number of Increment		Average Height	Time			Average Height	Time	Average Height	Time
			-65°F	77°F	160°F	-	77°F		
0		.108	.22	.18	.19	.108	.18	.108	.18
1		.266	1.58	1.39	1.34	.217	1.14	.332	1.98
2		.427	3.40	3.11	3.08	.331	2.31	.520	3.97
3		.573	5.08	4.62	4.53	.436	3.46	.721	6.02
5		.858	8.50	7.75	7.36	.647	5.51	1.089	9.93
7		1.153	11.64	10.36	10.02	.864	7.54	1.523	14.01
9		1.476	15.50	13.71	12.72			1.916	18.41
10						1.197	10.72		
12		1.923	20.49	17.92	17.24				
13						1.507	13.82		
16						1.820	16.33		

TABLE IV

F-2 Loaded in .156" Bodies

(Igniter - F33B - 30 mg Primer End - 20 mg Base - Flat Ram)

Increment Size No. Incr.	Mg.	100 Height (inches)	100 Time (seconds)	200 Height (inches)	200 Time (seconds)	300 Height (inches)	300 Time (seconds	200 Height (inches)	200 Time* (seconds)
0		.056	.22	.056	.22	.056	.22		
1		.115	.38		.56	.243	.72		
2		.179	.53	.307	.89	.446	1.27	.307	1.05
3				.436	1.23	.647	1.79		
4		.300	.88						
5				.693	1.94				
6									
7		.493	1.42						
8									
9									
10		.680	1.91						

* -65°F

TABLE V

M-2 Loaded in .156" Bodies

(Igniter - F33B - 30 mg Primer End - 20 mg Base End - Flat Ram)

Increment Size No. Incr.	Mg.	100 Height (inches)	100 Time (seconds)	200 Height (inches)	200 Time (seconds)	300 Height (inches)	300 Time (seconds)	200 Height (inches)	200 Time* (seconds)
0		.056	.22	.056	.22	.056	.22		
1		.124	.87	.199	1.41	.210	2.12		
2				.343	2.76	.509	4.21	.343	3.11
3		.269	2.15	.491	4.09	.730	6.14		
4									
5				.783	6.72				
6									
7		.557	4.71						
8									
9									
10		.770	6.57						

* -65°F.

TABLE VI

S-2 Loaded in .156" Bodies

(Igniter: F33B-30 mg Primer End, 20 mg Det. End, Flat Ram)

Increment Size	Mg	100	100	200	200	300	300	200	200
		Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time* (seconds)
0									
1		.127	1.17	.203	1.94	.283	2.58		
2				.355	3.73	.529	5.22	.355	3.88
3				.511	5.40	.766	7.69		
4		.350	3.62						
5				.819	8.69				
6									
7		.567	5.89						
8									
9									
10		.787	8.13						

* -65°F

TABLE VII
X-2 Loaded in .156" Bodies

(Igniter - F33B - 30 mg Primer End - 20 mg Base End - Flat Ram)

Increment Size	Mg.	100 Height (inches)	100 Time (seconds)	200 Height (inches)	200 Time (seconds)	300 Height (inches)	300 Time (seconds)	200 Height (inches)	200 Time* (seconds)
0									
1		.127	1.42	.208	2.29	.296	4.32		
2				.361	4.11	.506	6.07	.361	4.55
3				.518	6.36	.776	9.03		
4		.357	4.26						
5				.834	10.92				
6									
7		.589	7.09						
8									
9									
10		.814	7.59						

* at -65°F. (unreliable, since some duds occurred)

TABLE VIII

Mixture F-2 Loaded in .125" Bodies

(Igniter - F33B - 20 mg Primer End - 12 mg Base End - Flat Ram)

Increment Size No. Incr.	Mg.	75 Height (inches)	75 Time (seconds)	150 Height (inches)	150 Time (seconds)	250 Height (inches)	250 Time (seconds)	(-65°F. Mixture F-1) 150 Height (inches)	150 Time (seconds)
0									
1		.126	.40	.206	.65	.319	.92	.216	.66
2						.606	1.71		
3				.485	1.30	.885	2.00	.517	1.59
4		.344	.96						
5				.826	2.25				
6									
7		.567	1.53						
8									
9									
10		.779	2.10						

TABLE IX

Mixture M-2 Loaded in .125" Bodies

(Igniter - F33B - 20 mg Primer End - 12 mg Base End - Flat Ram)

Increment Size No. Incr.	Mg.	75 Height (inches)	75 Time (seconds)	150 Height (inches)	150 Time (seconds)	250 Height (inches)	250 Time (seconds)	(-65°F Mixture M-1) 150 Height (inches)	150 Time (seconds)
0									
1		.138	0.96	.229	1.79	.367	2.91	.236	1.96
2									
3		.311	2.60	.564	4.91	.692	5.58	.589	5.51
4									
5		.481	4.21	.935	8.31	1.055	8.46		
6									
7									
8									
9									
10		.915	8.17						

TABLE X

Mixture F-2 Loaded in .109" Diam. Bodies

(Igniter = F33B - 20 mg Primer End - 12 mg Base End - Flat Ram)

Increment Size No. incr.	Mg.	60 Height (inches)	60 Time (seconds)	125 Height (inches)	125 Time (seconds)	200 Height (inches)	200 Time (seconds)	(-65°F. Mixture M-1 125 mg Height (inches)	125 Time (seconds)
0									
1		.143	0.56	.235	.73	.345	98	.239	.74
2						.663	1.81		
3				.580	1.58			.579	1.91
4		.360	0.96	.437	2.01				
5									
6									
7		.606	1.58						
8									
9									
10		.810	2.11						

TABLE XI

Mixture M-2 Loaded in .109" Bodies

(Igniter - F33B - 20 mg Primer - 12 mg Base End - Flat Ram)

Increment Size	Mg.	60 Height (inches)	60 Time (seconds)	125 Height (inches)	125 Time (seconds)	200 Height (inches)	200 Time (seconds)
0							
1		.157	1.02	.267	1.93	.415	3.03
2						.771	5.87
3				.652	5.49		
4		.413	3.46	.860	7.23		
5							
6							
7		.688	6.12				
8							
9							
10		.976	8.43				

TABLE XII

Results of Minimum Igniter Studies in .203"Bodies

Type Loading	Amount of Igniter	Room Temperature (77°F) 70 mg	50 mg	30 mg	20 mg	10 mg	Cold Box (-65°F) 50 mg	30 mg	20 mg
Cone up		+	+	+	+	0	+	0	0
		+	+	+	+	0	+	+	0
		+	+	+	+	0		0	0
Cone down		+	+	+	+	+	+	+	+
		+	+	+	+	+	+	0	0
		+	+	+	+	+	+	+	0
Flat ram		+	+	+	+	0	+	+	+
		+	+	+	+	0	+	+	+
		+	+	+	+	0	+	+	+

0 Duds

\+ Satisfactory Ignition

TABLE XIII

Burning Times and Column Heights as a Function of Different Rams for all Mixtures Loaded in .203" Diameter Bodies

(Igniter-F33B-100 mg Primer End, 70 mg Base End, Cone Ram)

Mixture	F-2		M-2		S-2		X-2	
No. Increment	Ht. (In.)	Time (Sec.)	Ht. (In.)	Time (Sec.)	Ht. (In.)	Time (Sec.)	Ht. (In.)	Time (Sec.)
(350 mg)								
1								
2	.383	1.02	.407	2.68	.426	3.39	.434	3.86
3	.516	1.40	.570	4.06	.581	4.97	.595	5.92
4								
5	.769	2.08	.869	6.60	.904	8.54	.916	9.94

(Igniter-F33B-50 mg Primer End, 30 mg Base End, Flat Ram)

(350 mg)								
1								
2	.312	1.00	.349	2.79	.359	3.61	.342	4.25
3	.444	1.36	.497	4.10	.516	5.34	.527	6.16
4								
5	.711	2.10	.792	6.62	.836	8.79	.845	10.10

TABLE XIV

Burning Characteristics as a Function of Body I.D.

Mixture	Diameter in.	Cross Section Area in.	Room Temperature Burning Time (sec/in)	Room Temperature Burning Rate (in/sec)	Burning* Room Temperature	Burning* -65°F
F-2	.203	.0305	3.00	0.33	B	B
"	.156	.0192	2.80	0.36	B	B
"	.125	.0123	2.50	0.40	B	B
"	.109	.0093	2.80	0.36	B	B
M-2	.203	.0305	8.60	0.116	B	B
"	.156	.0192	8.80	0.114	B	B
"	.125	.0123	9.10	0.110	B	F
"	.109	.0093			B	F
S-2	.203	.0305	10.90	.092	B	B
"	.156	.0192	11.00	.091	B	B
"	.125	.0123			F	F
"	.109	.0093			F	F
X-2	.203	.0305	12.40	.081	B	B
"	.156	.0192			B	F
"	.125	.0123			F	F
"	.109	.0095			F	F

*B = Burned Satisfactorily

*F = Failed to Burn

TABLE XV

Effect of Loading Pressure on Packed
Density and Burning Rate of Delay Powders

(.203" Bodies, M-2 Mixture, Flat Ram 3 Increments of 350 mg 50 + 30 mg of F33B)

Dial Reading	Pressure (psi)	Average Column Height (inches)	Average Burning Time (seconds)	Average Burning Rate (inches/second)
29	21,200	.518	4.18	.124
35	25,600	.511	4.14	.124
41	30,000	.505	4.04	.125
47	34,400	.496	4.00	.124
53	38,800	.492	3.91	.126

TABLE XVI
Burning Times of Sealed Bodies

Shot	Series	F33B Primer End	Weight Delay Powder	F33B Base End	Delay* Column Length (inches)	Burning Time (Seconds)
1	A & B	50	0	1400	.050	.20
		50	0	1400	.050	.21
		50	0	1400	.050	.22
2	A	50	350	1200	.190	1.17
3	A	50	700	950	.350	2.10
		50	700	950	.350	2.13
4	A	50	1050	700	.495	3.17
		50	1050	700	.495	3.00
5	A	50	1200	580	.560	3.59
		50	1200	580	.560	3.60
6	A	50	1400	450	.645	4.14
7	A	50	1750	200	.795	5.14
		50	1750	200	.795	5.15
8	A & B	50	2100	30	.945	6.11
		50	2100	30	.945	6.07
		50	2100	30	.945	6.06
2a	B	1200	350	30	.190	.93
3a	B	700	1050	30	.495	2.38
		700	1050	30	.495	2.44
7a	B	250	1750	30	.795	4.34
		250	1750	30	.795	4.41

*Delay Column Length = Length for Delay Powder + Length for 80 mg F33B (50 Primer End 30 Det. End)

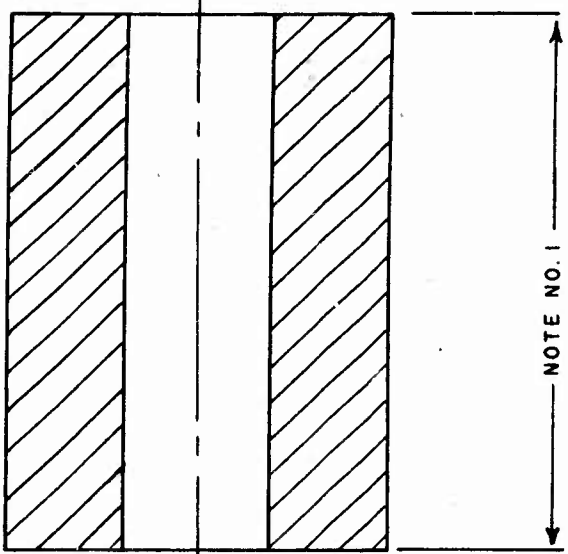
TABLE XVII

Recommended Limits for Loading Variables

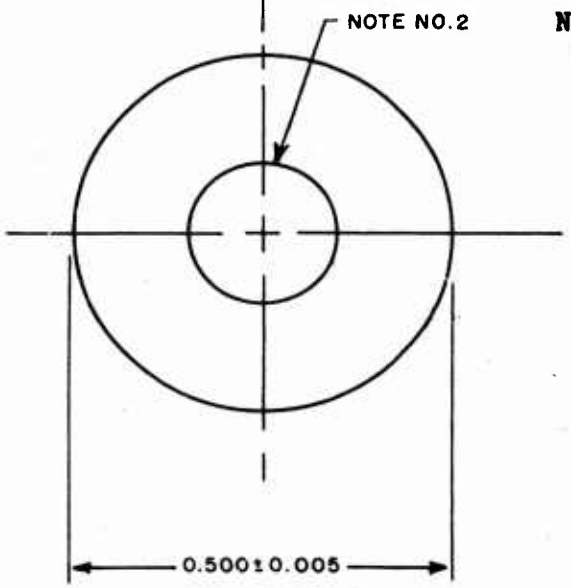
Body Size I.D.	Increment		Igniter Charge	Pressure	
	Maximum	Minimum		Maximum	Minimum
				psi	
.203"	700	200	50	31,500	28,500
.156"	300	150	30	31,500	28,500
.125"	150	65	20	31,500	28,500
.109"	125	50	20	31,500	28,500

PLATE 1

VENTED BODIES



NOTE 1 - OVERALL LENGTHS VARY ACCORDING TO SIZE OF DELAY COLUMN



NOTE 2 - HOLE REAMED AS FOLLOWS:

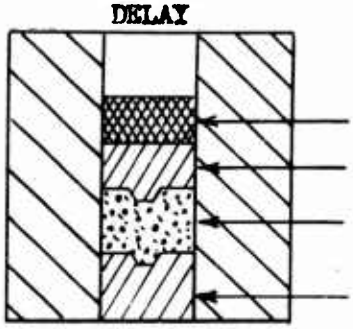
NORMAL BODY SIZE	HOLE DIMENSION
0.109	$0.109^{+0.001}_{-0.000}$
0.125	$0.125^{+0.001}_{-0.000}$
0.156	$0.156^{+0.001}_{-0.000}$
0.203	$0.203^{+0.001}_{-0.000}$

MATERIAL VARIED AS FOLLOWS:

a - BRASS
b - COPPER
c - STAINLESS STEEL

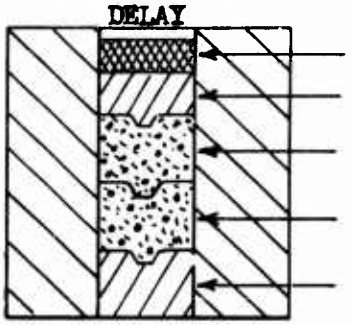
PLATE 2
LOADING PROCEDURE
VENTED BODIES, CONE RAM

1-INCREMENT DELAY



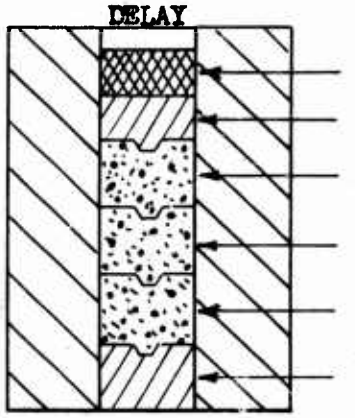
A-5 BLACK POWDER, 30,000 PSI, FLAT RAM.
BASE IGNITER, MACH. PRESS 30,000 PSI, FLAT RAM.
DELAY, 1-INCREMENT, HAND PRESSED, CONE RAM.
F-33-B PRIMER END, HAND PRESSED, CONE RAM.

2-INCREMENT DELAY



A-5 BLACK POWDER, 30,000 PSI, FLAT RAM.
BASE IGNITER, MACH. PRESS 30,000 PSI, FLAT RAM.
2ND DELAY INCREMENT, HAND PRESS, CONE RAM.
1ST DELAY INCREMENT, MACH. PRESS 30,000 PSI CONE RAM.
IGNITER PRIMER END, HAND PRESS, CONE RAM.

3-INCREMENT DELAY

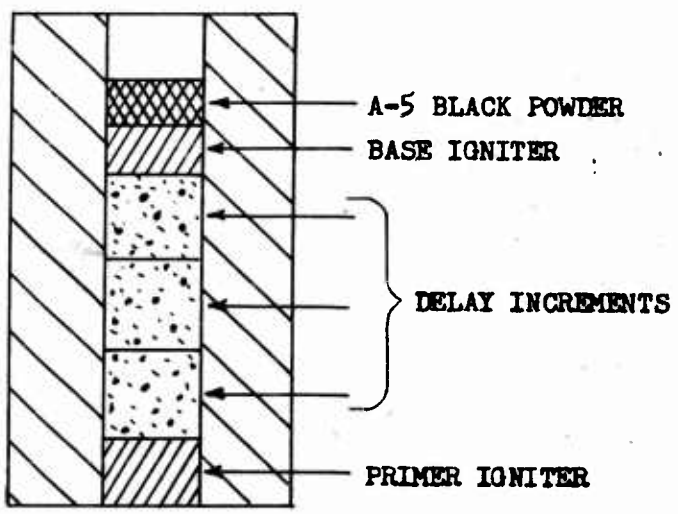


A-5 BLACK POWDER, 30,000 PSI, FLAT. RAM.
BASE IGNITER, 30,000 PSI MACH. PRESS, FLAT RAM.
LAST DELAY INCREMENT, HAND PRESS, CONE RAM.
2ND DELAY INCREMENT, MACH. PRESS 30,000 PSI, CONE RAM.
1ST DELAY INCREMENT, MACH. PRESS 30,000 PSI, CONE RAM.
PRIMER END IGNITER, HAND PRESS, CONE RAM

AS NUMBER OF DELAY INCREMENTS INCREASE, LOADING IS UNCHANGED. (ALL ADDITIONAL DELAY INCREMENTS MACHINE PRESSED AT 30,000 PSI, AND LAST INCREMENT HAND PRESSED BEFORE BEING PRESSED TOGETHER WITH BASE IGNITER).

PLATE 3

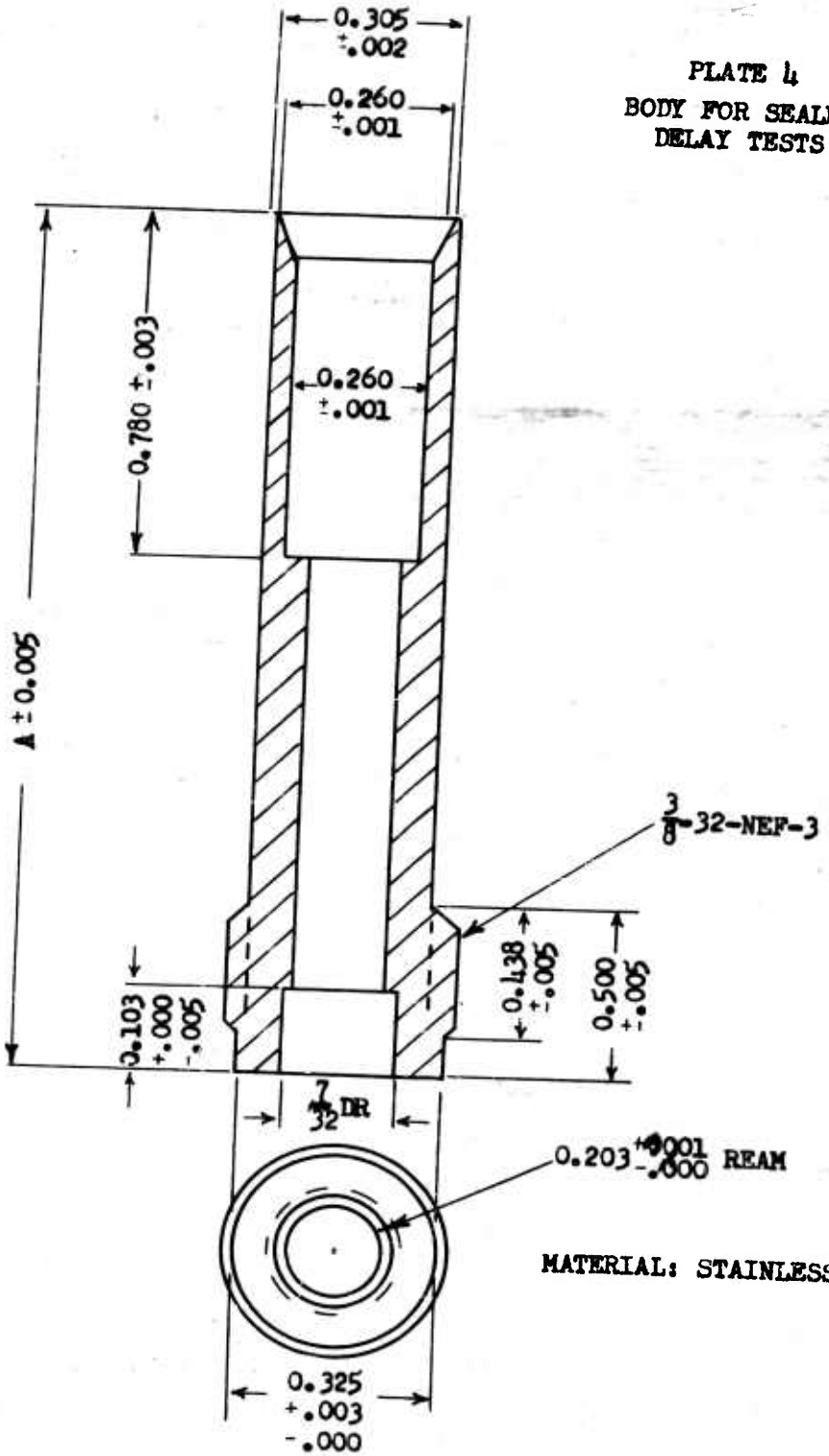
LOADING PROCEDURE
VENTED BODIES, FLAT RAM



ALL INCREMENTS, REGARDLESS OF NUMBER, IGNITER, DELAY OR A-5 BLACK POWDER PRESSED SEPARATELY WITH FLAT RAM AT 30,000 PSI

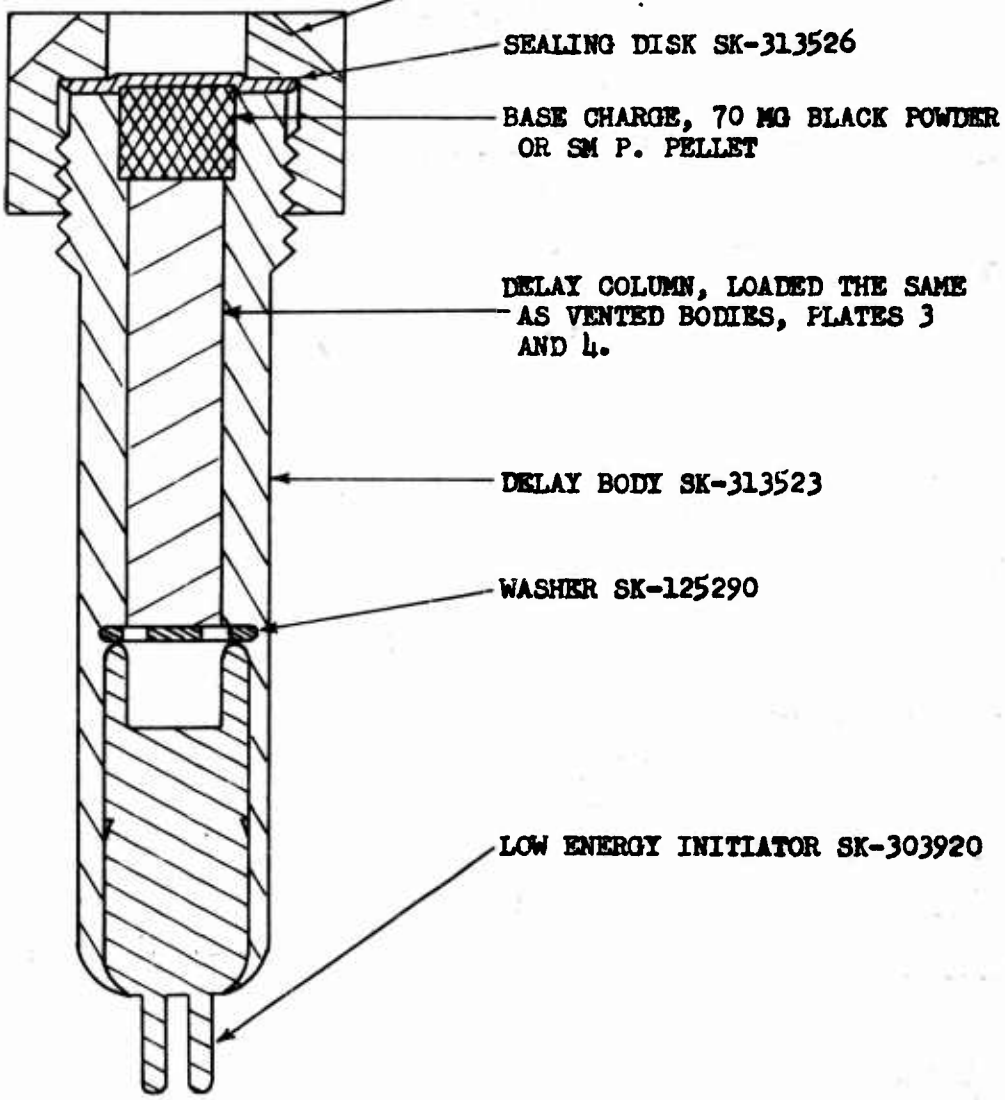
PLATE 4

BODY FOR SEALED DELAY TESTS



MATERIAL: STAINLESS STEEL

PLATE 5
SEALED DELAY ASSEMBLY



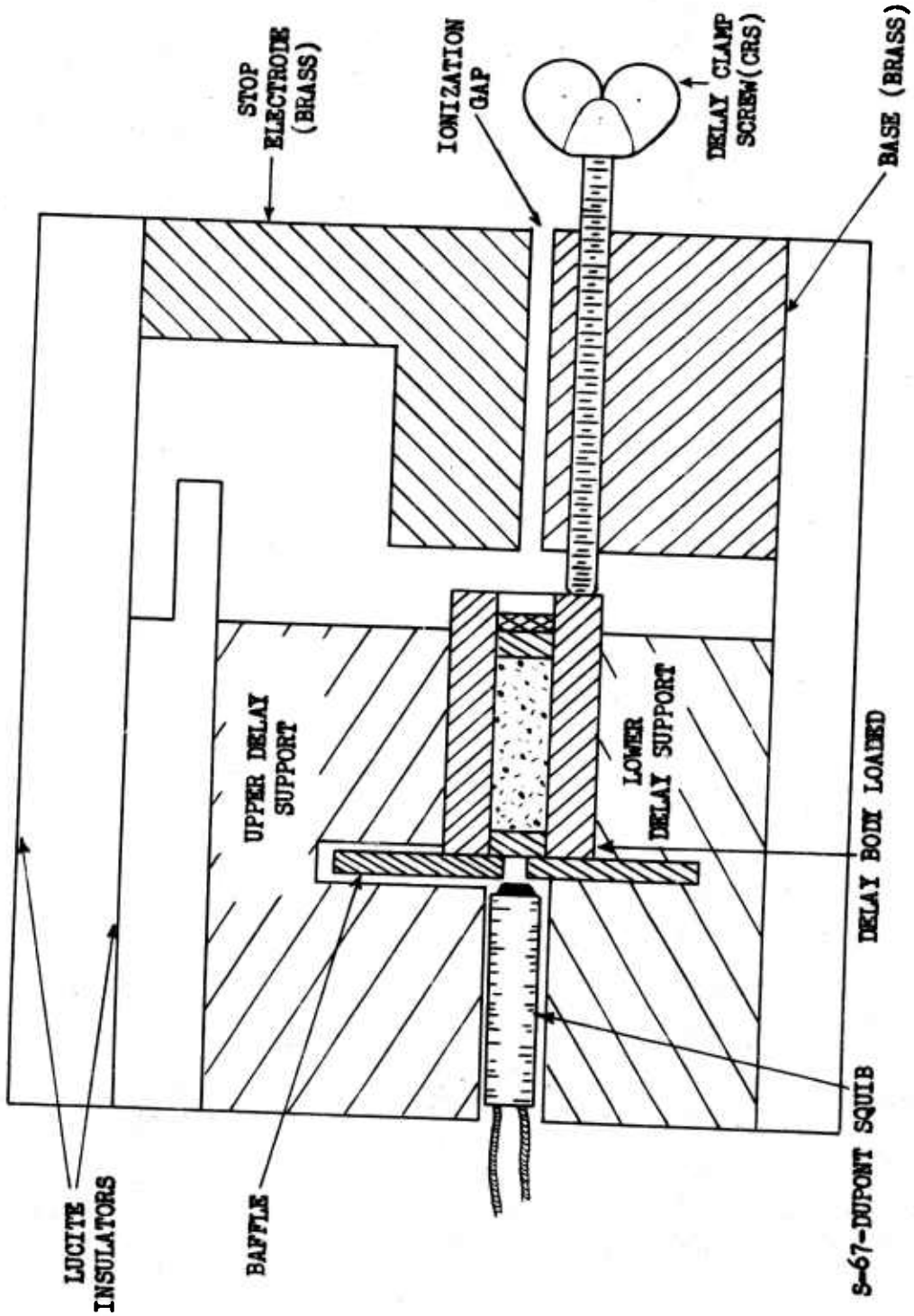


PLATE 6

VENTED BODY FIRING ARRANGEMENT

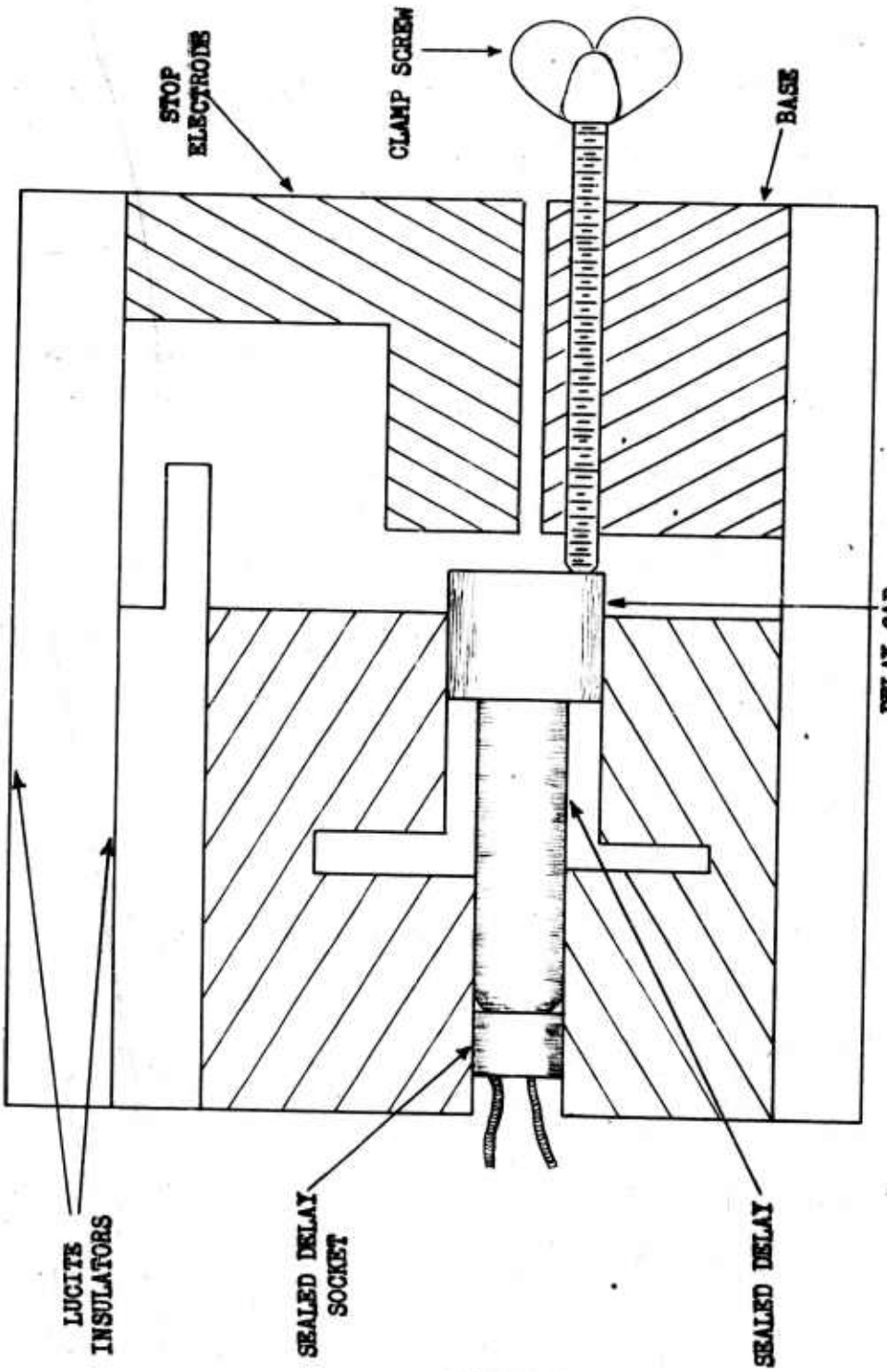


PLATE 7

SEALED BODY FIRING ARRANGEMENT

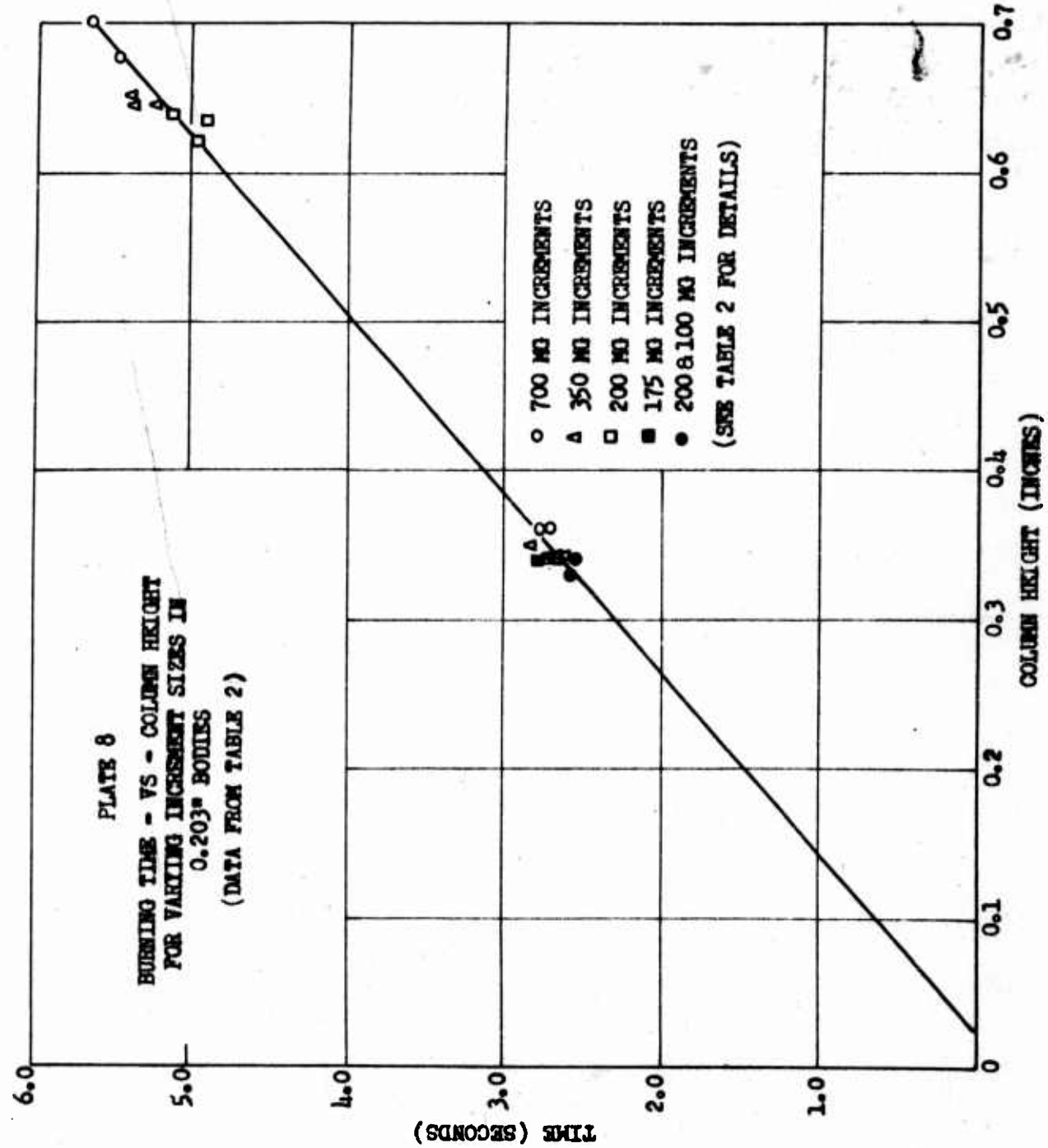


PLATE 8
BURNING TIME - VS - COLUMN HEIGHT
FOR VARYING INCREMENT SIZES IN
0.203" BOULES
(DATA FROM TABLE 2)
TIME (SECONDS)
COLUMN HEIGHT (INCHES)
6.0
5.0
4.0
3.0
2.0
1.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
○ 700 MG INCREMENTS
△ 350 MG INCREMENTS
□ 200 MG INCREMENTS
■ 175 MG INCREMENTS
● 200 & 100 MG INCREMENTS
(SEE TABLE 2 FOR DETAILS)

PLATE 9

BURNING TIME - VS - COLUMN LENGTH
FOR STANDARD D-7 MIXTURE

0.203" BODY, CONE RAM
100 MG F33B PRIMER END
70 MG F33B BASE END

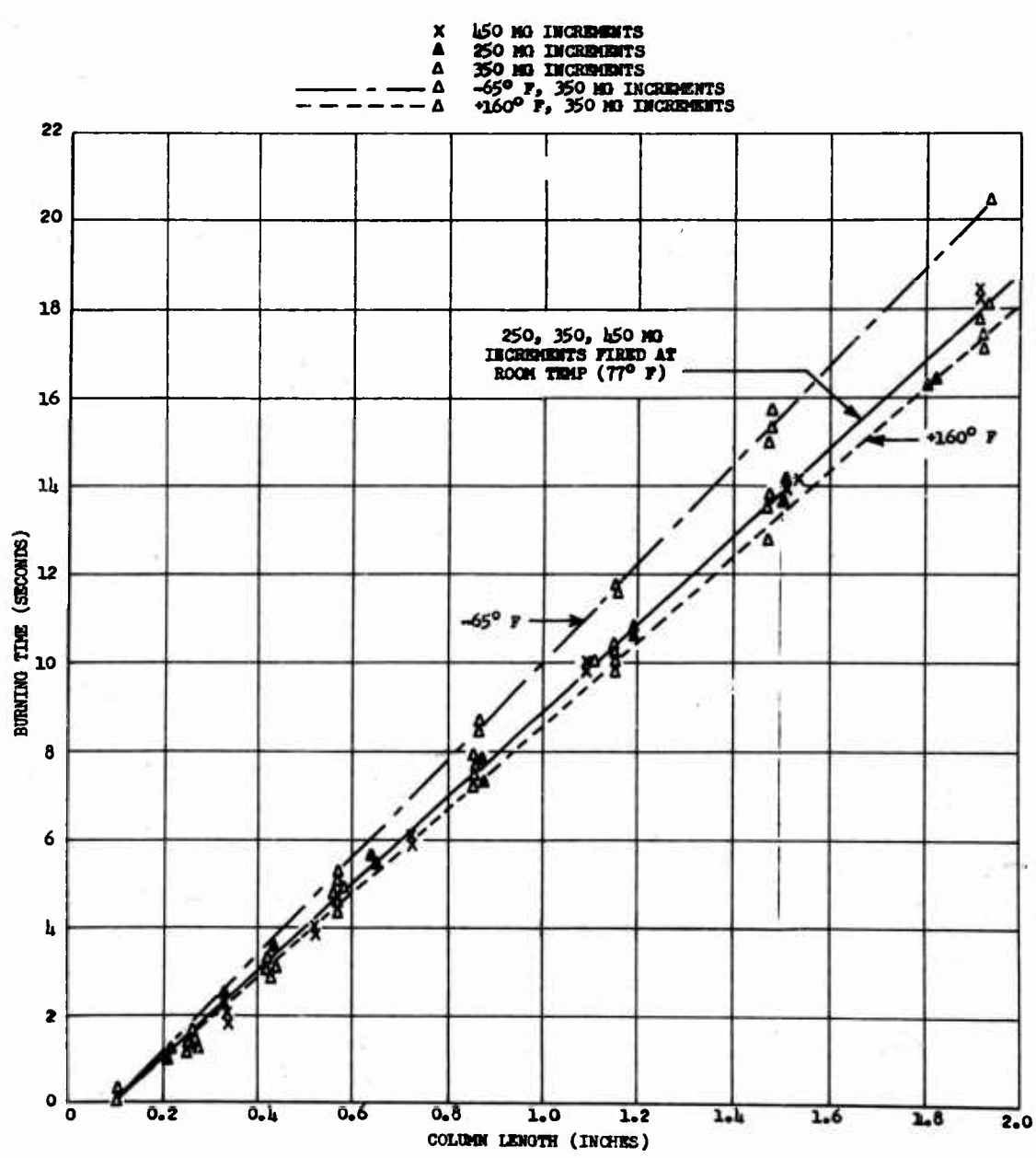


PLATE 10

BURNING TIME & COLUMN LENGTH VS
NUMBER OF INCREMENTS DELAY (D-7)
(350 MG INCREMENTS)

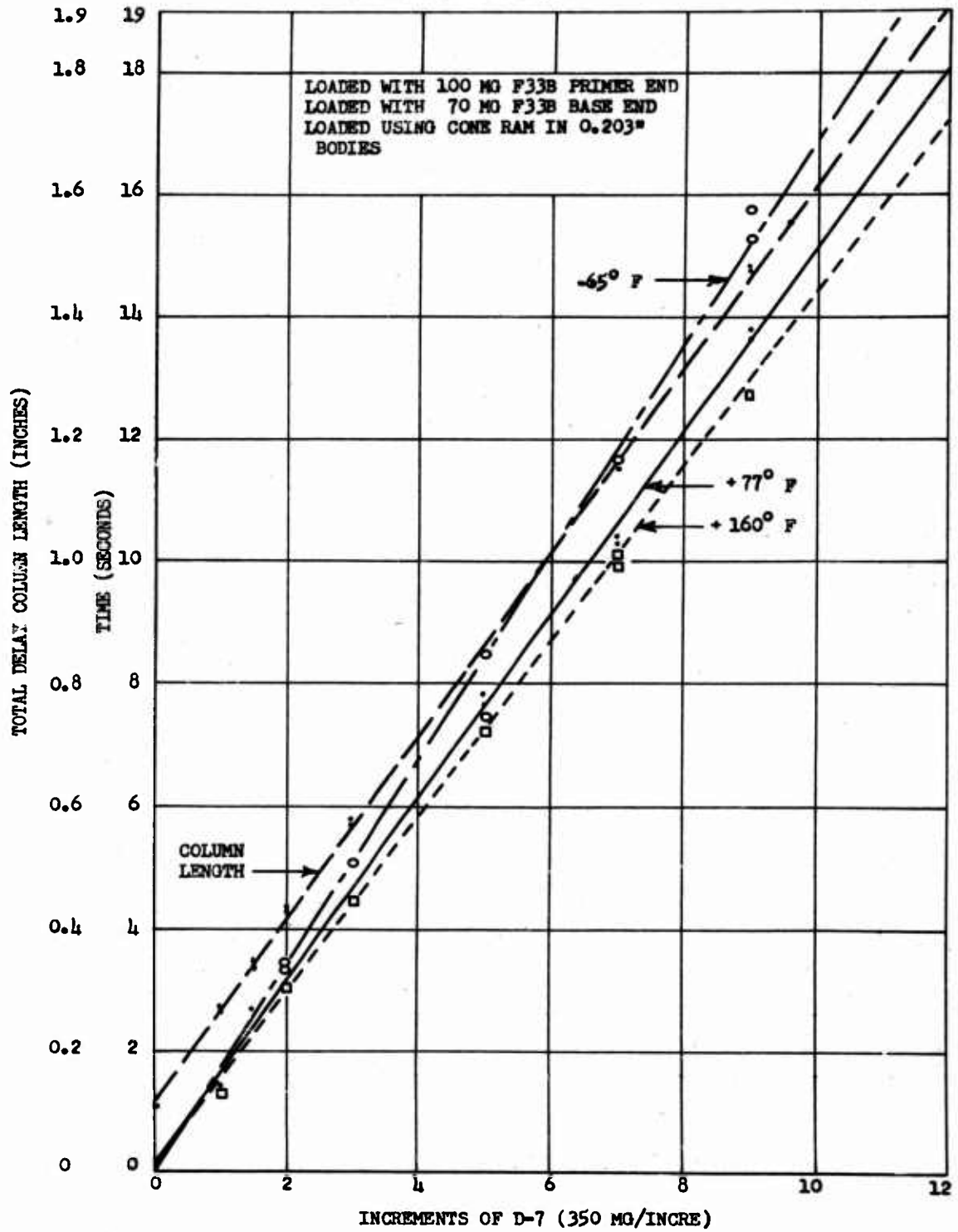


PLATE 11

BURNING TIME AND COLUMN HEIGHT
FOR 250 MG AND 450 MG INCREMENTS
(STANDARD D-7 MIX.)

0.203 DIAM CONE RAM
100 MG F33B PRIMER END
70 MG F33B BASE END

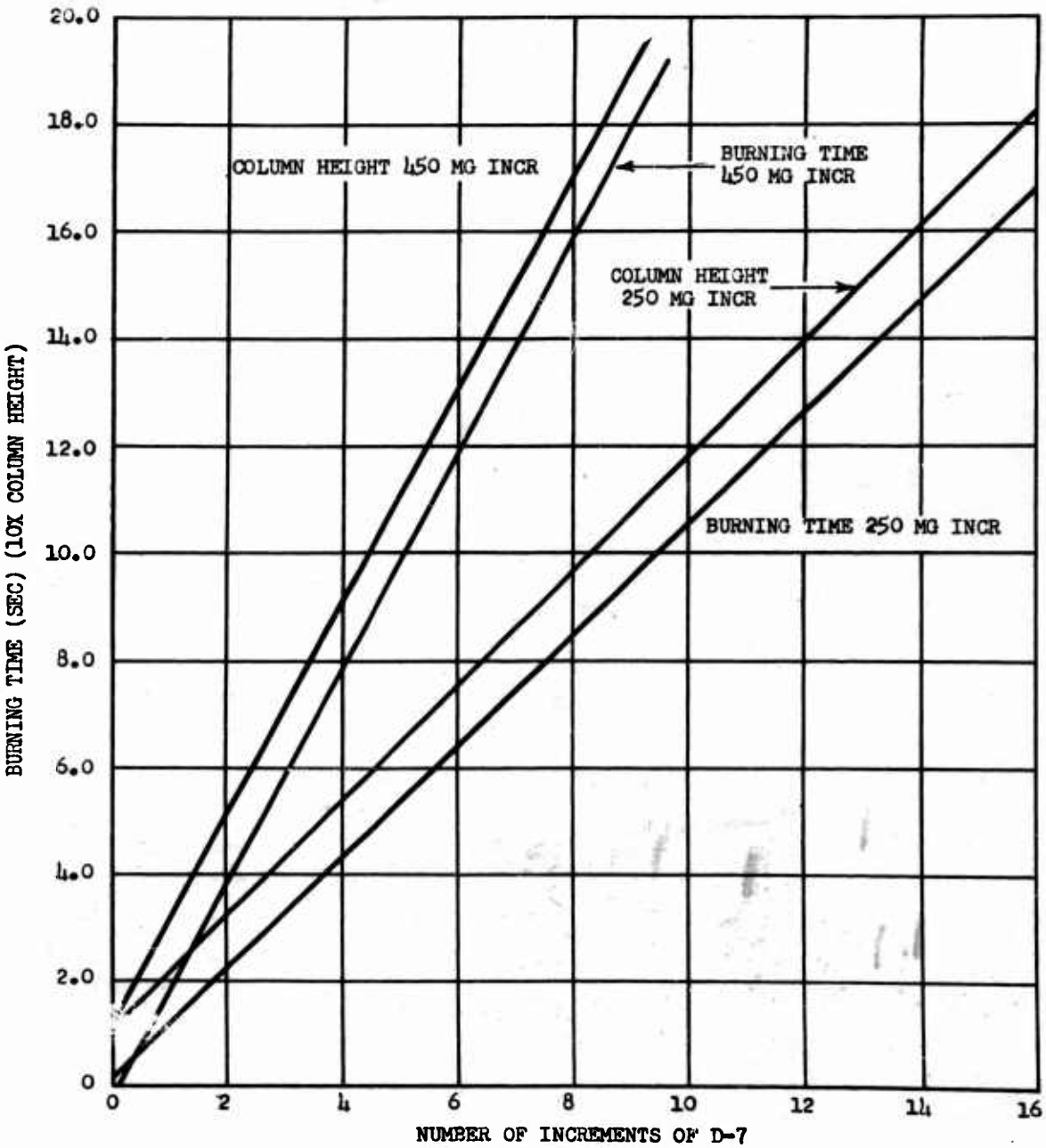


PLATE 12 BURNING TIME vs COLUMN HEIGHT

0.156" BODIES, FLAT RAM

ALL FIRED AT ROOM TEMPERATURE — IGNITER: 30 mg PRIMER END
20 mg BASE END

× 100 mg INCREMENTS
● 200 mg INCREMENTS
○ 300 mg INCREMENTS

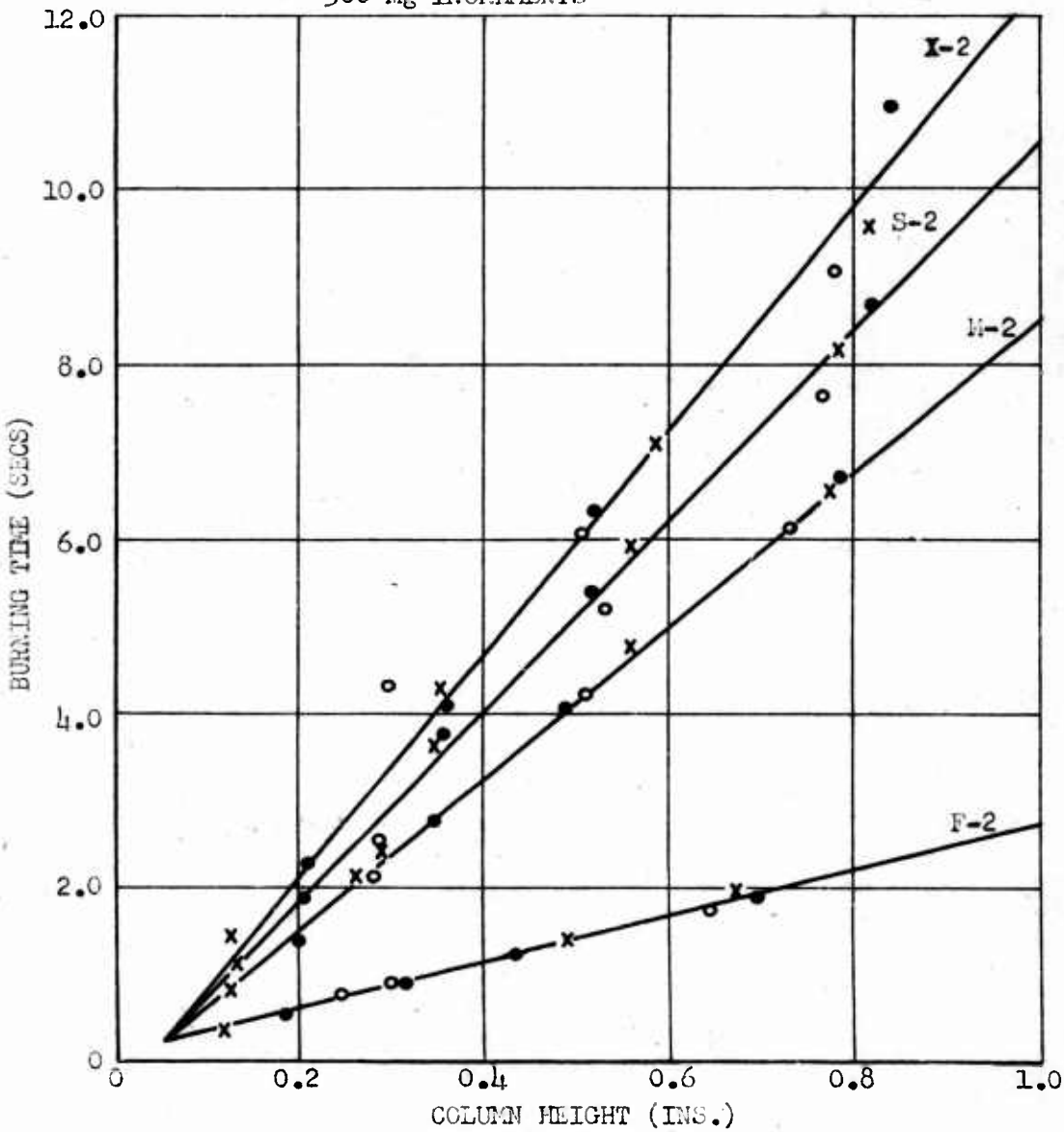


PLATE 13 BURNING TIME vs COLUMN HEIGHT

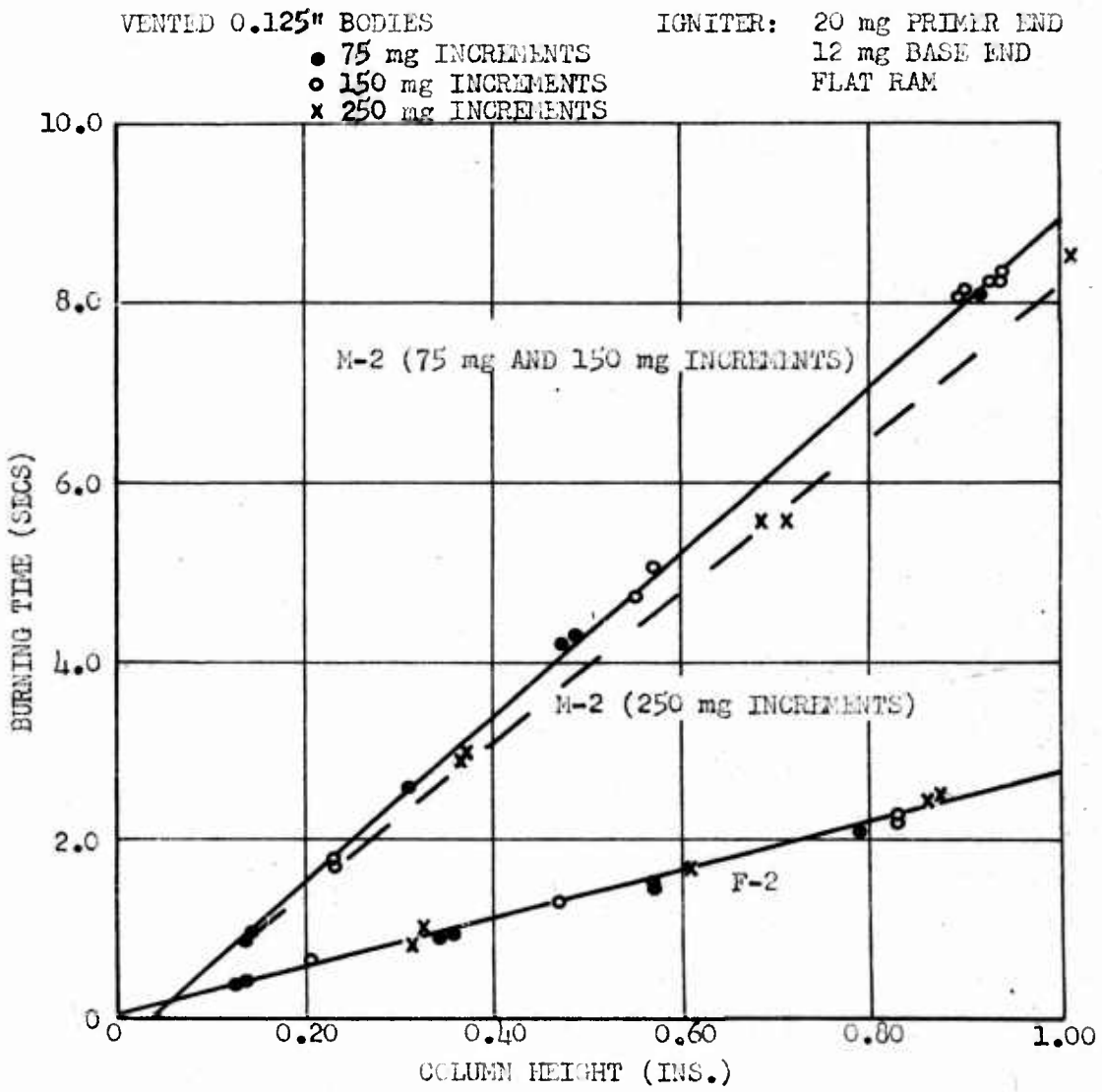


PLATE [illegible] BURNING TIME vs COLUMN [illegible]IGHT

VENTED 0.109" [illegible]ODIES — IGNITER: 20 mg PRIMER END, 12 mg BASE END, FLAT RAM

● 60 mg
○ [illegible]
× [illegible]

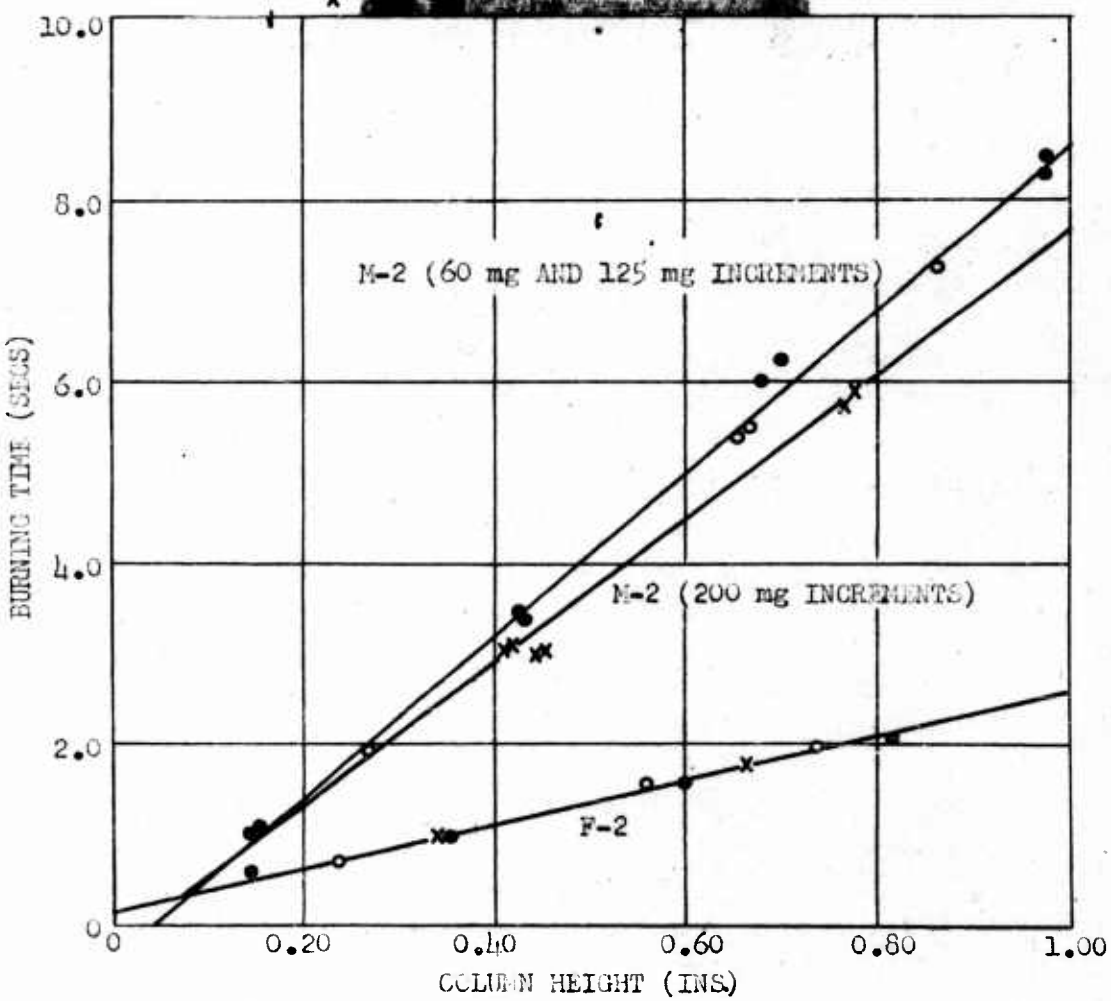
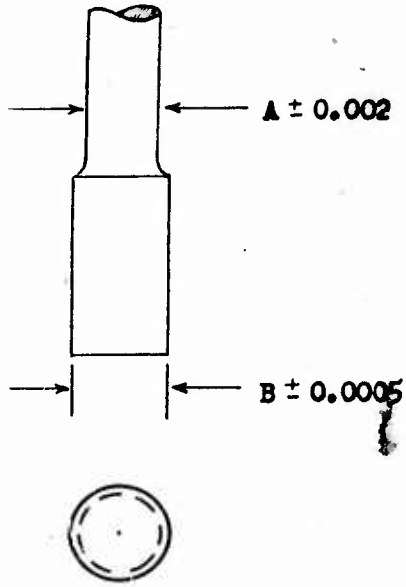


PLATE 15

DIMENSIONS OF RAMS

1 - FLAT RAM

BODY TO BE LOADED	DIMENSIONS A	B
0.203"	0.201	0.175
0.156"	0.154	0.135
0.125"	0.124	0.110
0.109"	0.108	0.090



2 - CONE RAM

CONE RAM USED ONLY IN 0.203" DIAMETER BODY

FOR FULL DETAILS OF RAMS SEE:
NOL-SK-313190
SK-313188

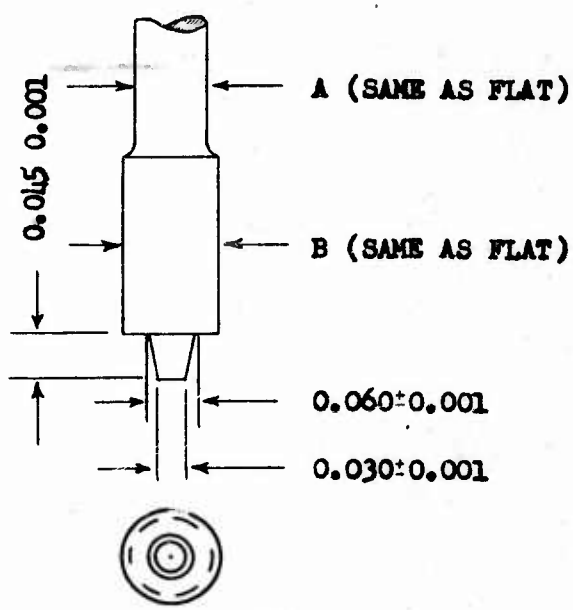
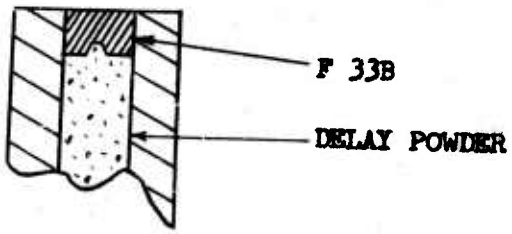


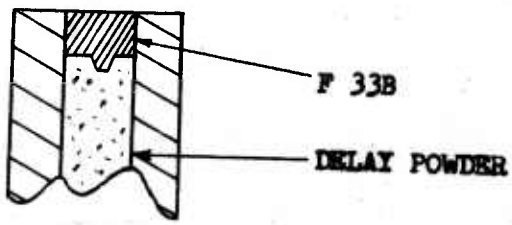
PLATE 16

MINIMUM IGNITER STUDIES

CONE UP



CONE DOWN



FLAT RAM

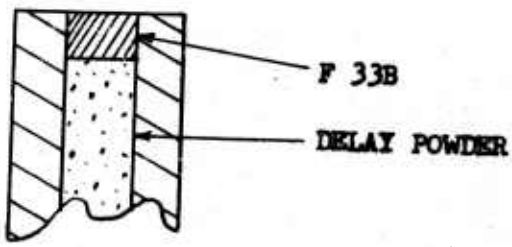


PLATE 17 BURNING TIME vs NUMBER OF INCREMENTS

(LOADED WITH 50 mg F33B PRIMER END
AND 30 mg F33B BASE END USING FLAT RAM.)

0.203" BODIES

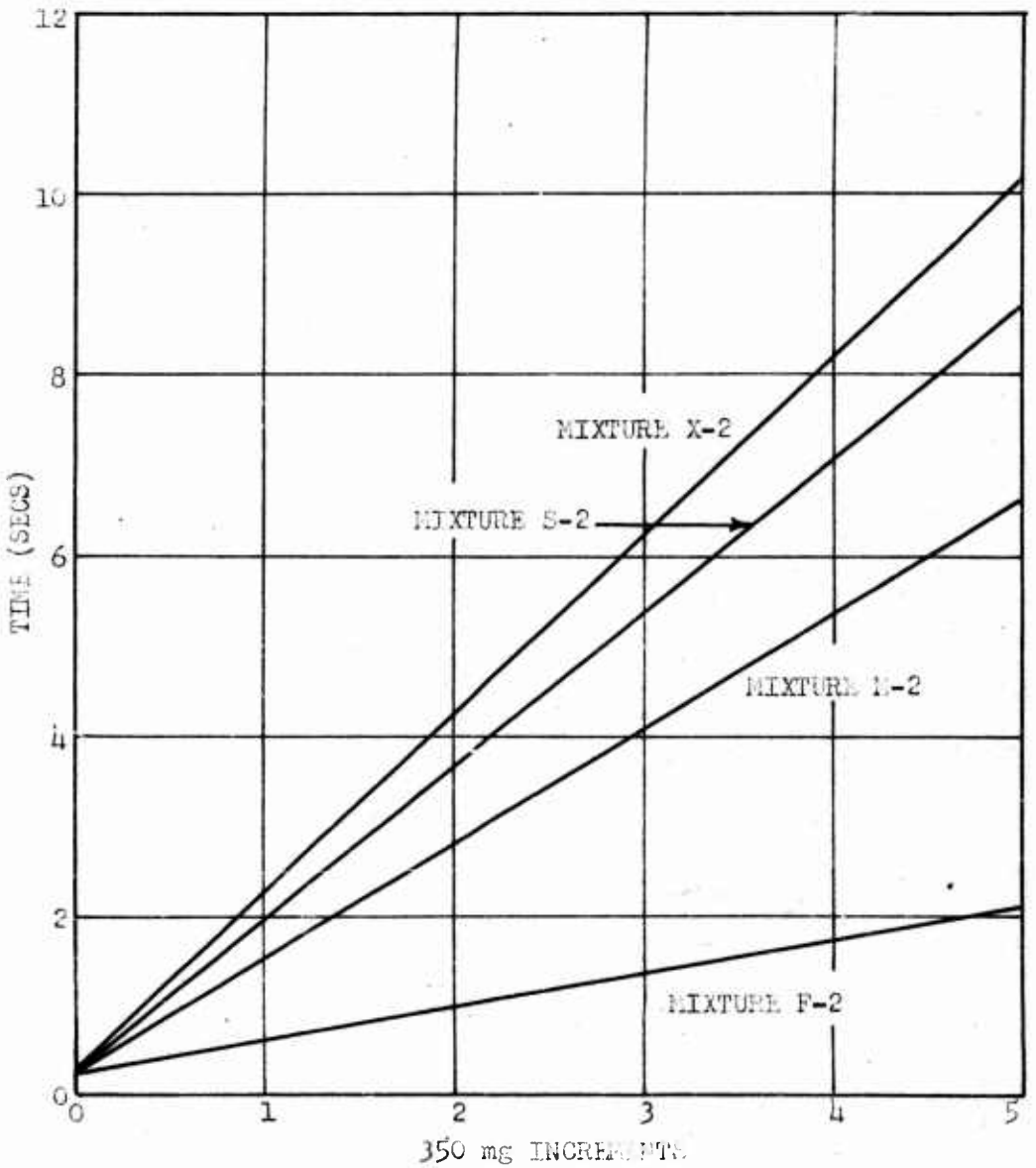


PLATE 18

BURNING TIME VS NUMBER OF INCREMENTS
(LOADED WITH 100 MG F33B PRIMER END
LOADED WITH 70 MG F33B BASE END
LOADED USING CONE RAM.)

0.203" BODIES

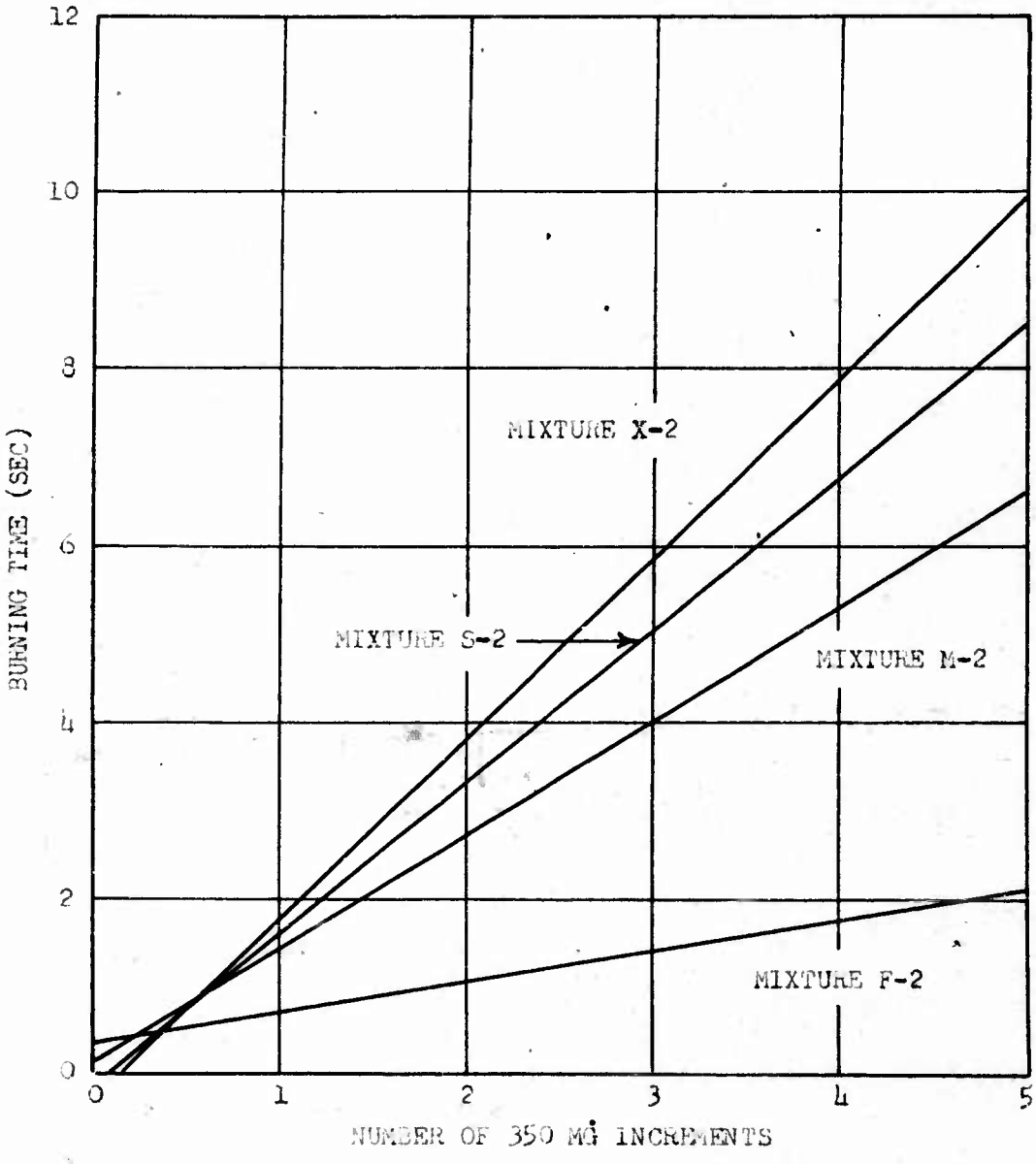


PLATE 19 BURNING TIME vs COLUMN HEIGHT

FLAT RAM - 0.203" BODIES
350 mg INCREMENTS
50 mg F33B PRIMER END
30 mg F33B BASE END

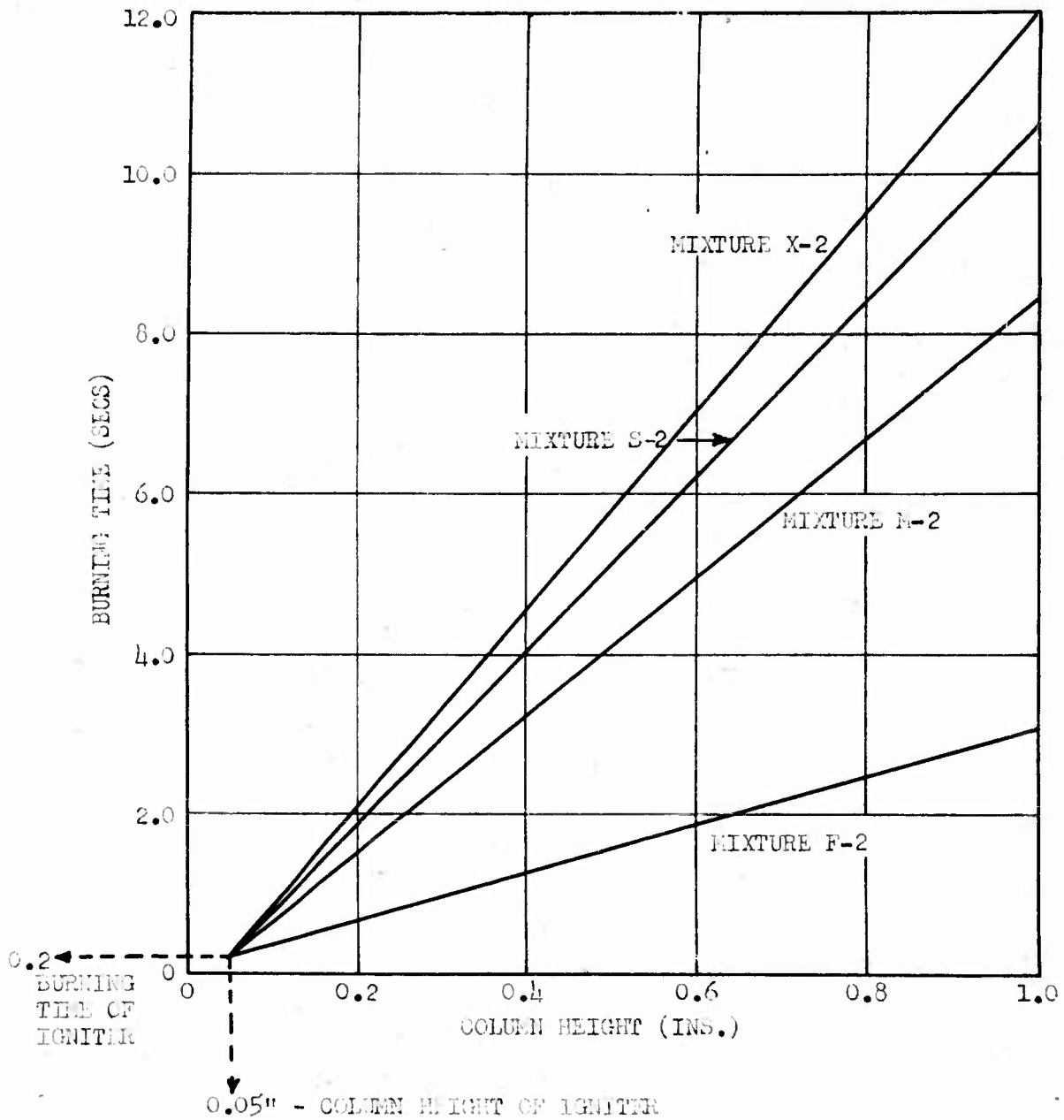


PLATE 20

BURNING TIME VS COLUMN HEIGHT
CONE RAM LOADING IN 0.203" BODIES, 350 MG INCREMENTS

100 MG F33B PRIMER END
70 MG F33B BASE END

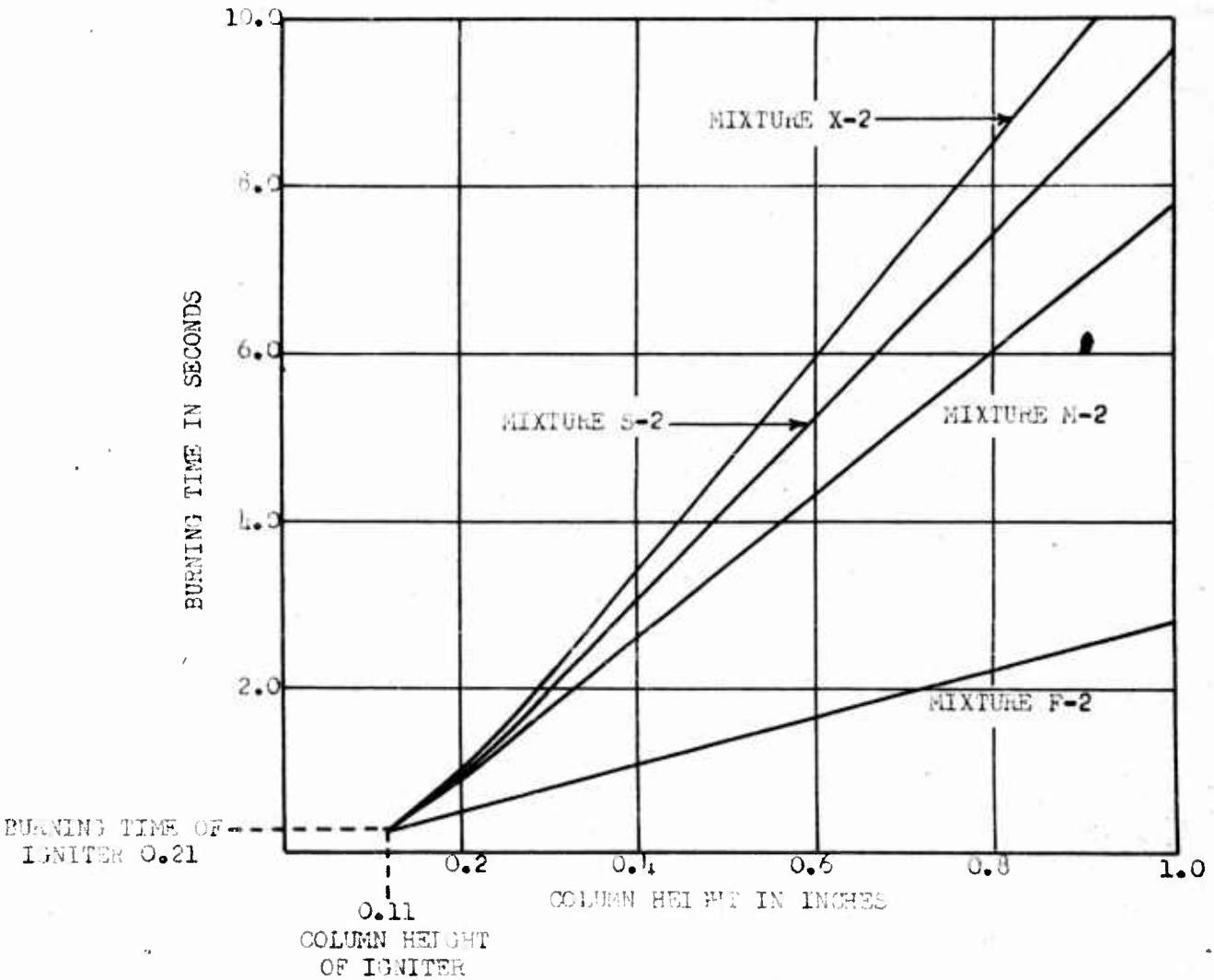


PLATE 21 COLUMN HEIGHT vs WEIGHT OF DELAY

0.203" BODIES

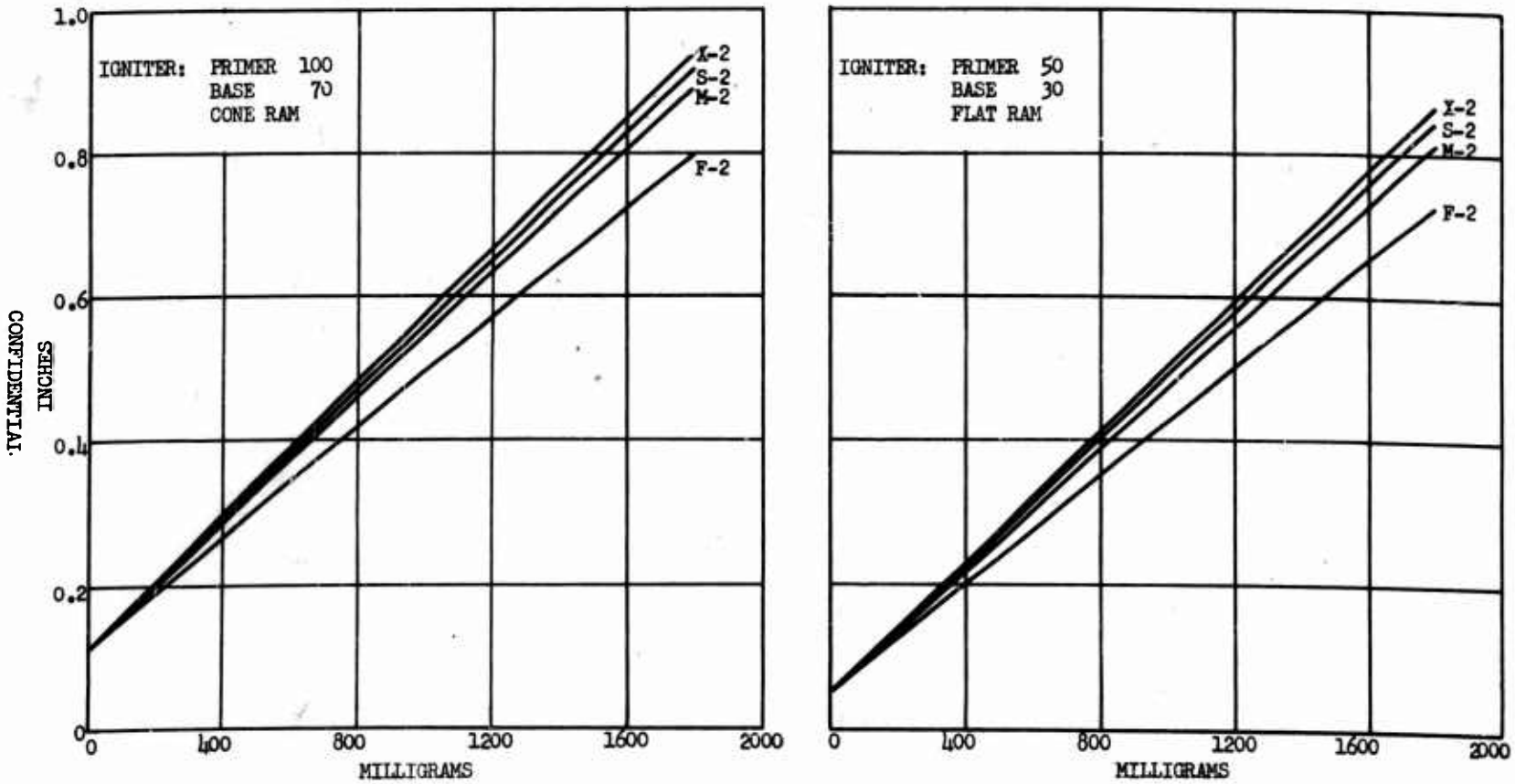
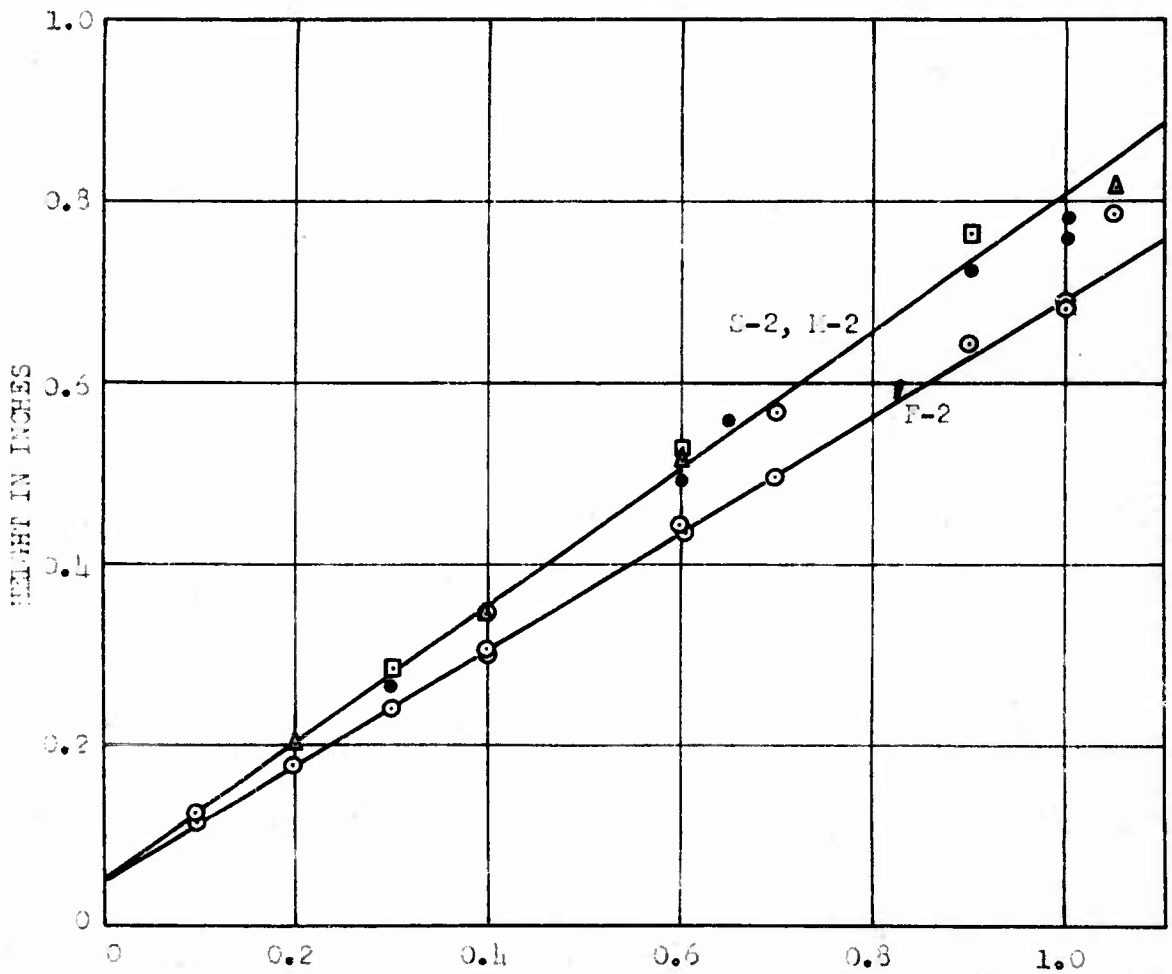


PLATE 22

HEIGHT OF DELAY
COLUMN VS WEIGHT DELAY POWDER
0.156" BODY



WEIGHT OF DELAY POWDER IN GRAMS
INCLUDING 30 MG F33B PRIMER END
AND 20 MG F33B BASE END, FLAT RAM.

PLATE 23 HEIGHT OF COLUMN vs WEIGHT OF DELAY POWDER

IGNITER: 20 mg PRIMER
12 mg BASE END
FLAT RAM

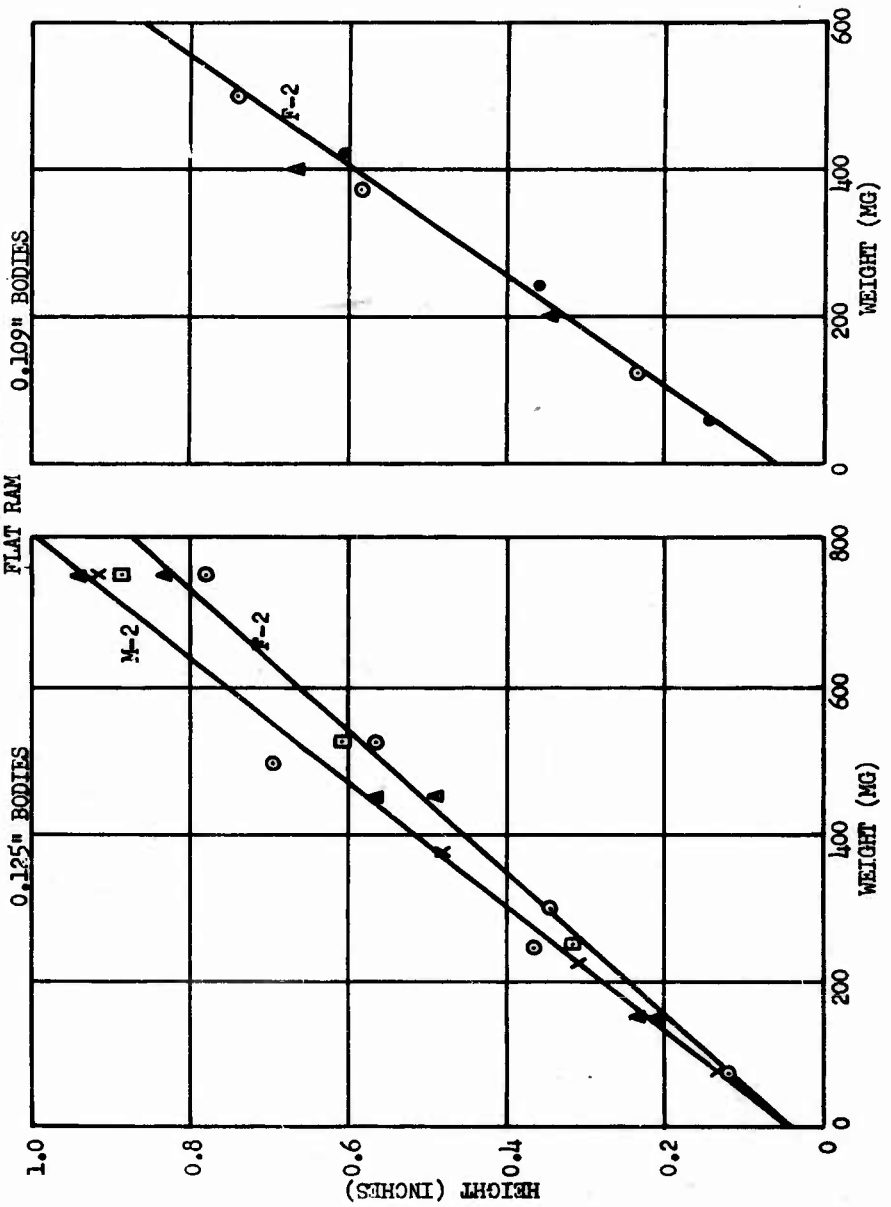
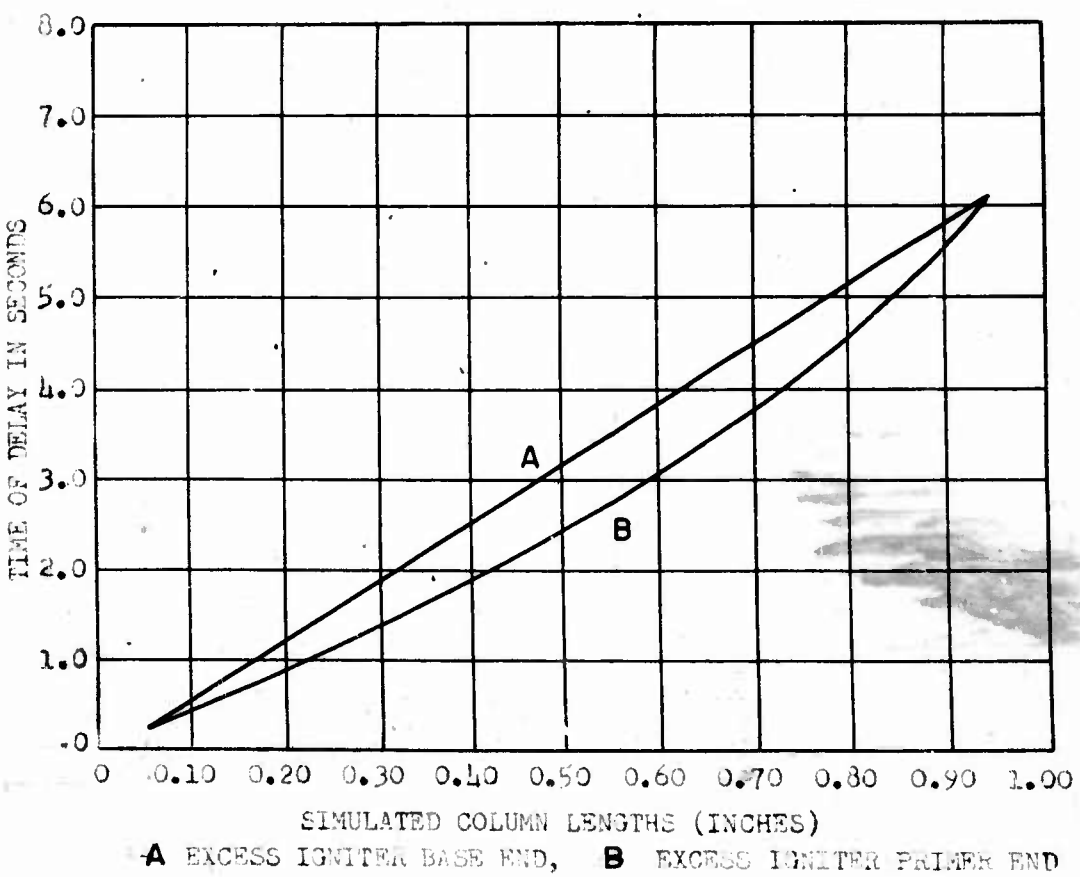


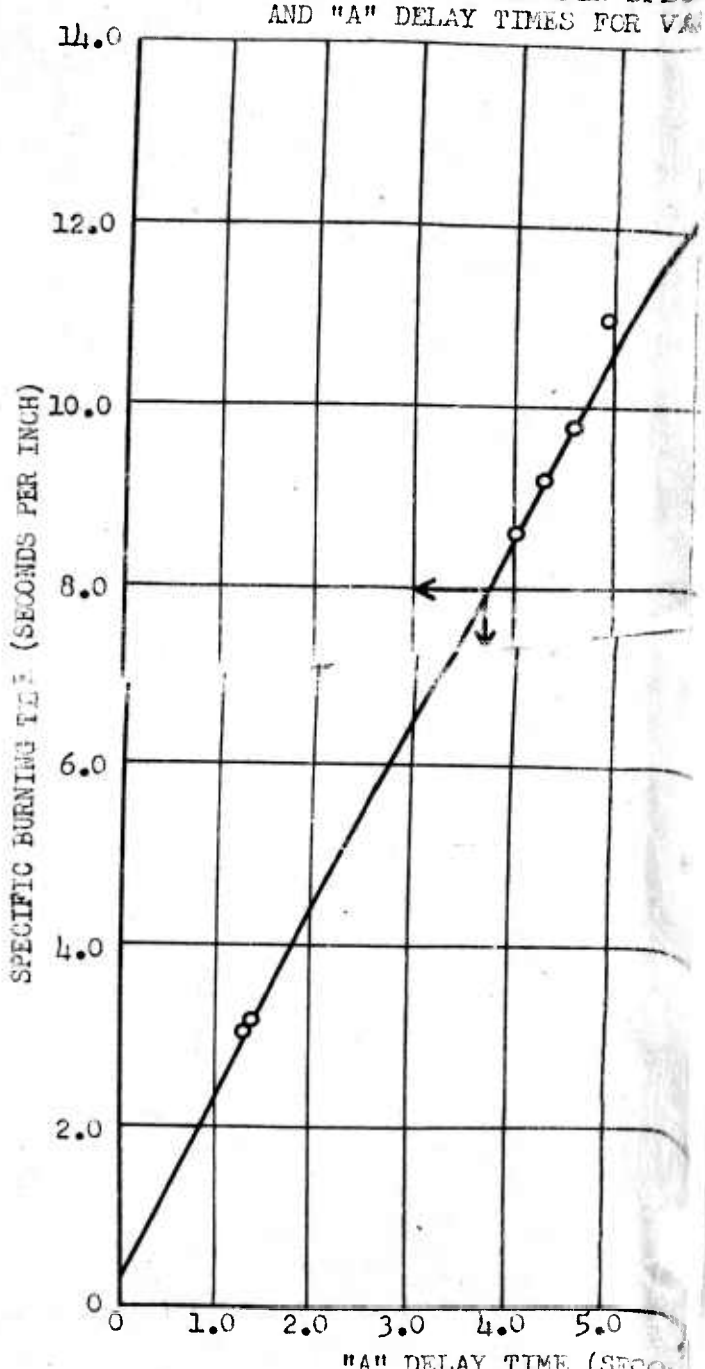
PLATE 24

BURNING TIME OF DELAY VS SIMULATED COLUMN LENGTHS
IN OBTURATED BODIES. USING MIXTURE M-1



A EXCESS IGNITER BASE END, B EXCESS IGNITER PRIMER END

PLATE 25 RELATION BETWEEN SPEC
AND "A" DELAY TIMES FOR V



A DELAY = 100 mg F33B + THREE 350 mg DE